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INSTRUCTION MANUALS
FOR MODELS 300
320A

300
320A

A-260 VENDOR FILES
HOLD COPY #1

BALLANTINE

MISSILE & SPACE SYSTEMS DIVISION
DOUGLAS AIRCRAFT COMPANY, INC.
SANTA MONICA/CALIFORNIA

MP MASTER
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INSTRUCTIONS FOR

AC ELECTRONIC VOLTMETER

MODEL 300

BALLANTINE LABORATORIES, INC.
BOONTON, NEW JERSEY

INSTRUCTIONS FOR

AC ELECTRONIC VOLTMETER

MODEL 300

GENERAL — This voltmeter is designed to measure sinusoidal voltages from 1 millivolt to 100 volts over a frequency range from 10 to 150,000 cps. It operates from a 110-120 volt 50-420-cycle power supply. 230-volt models are also available on special order as are other special versions having the characteristics described on page 10.

By means of a five decade range switch, the entire voltage range is indicated on a single logarithmic voltage scale reading from 1 to 10. The indicating meter also has a uniform decibel scale, numbered from 0 to 20 decibels. The zero of the decibel scale is arbitrarily arranged for maximum usefulness so as to correspond to 1 on the voltage scale.

Its accuracy is 2% from 10 to 150,000 cycles. Since the scale is logarithmic the accuracy is the same at any point on the scale.

An ac output jack permits the amplifier section of the voltmeter to be used as a flat high gain amplifier with an adjustable gain from 0 to 70 db.

GENERAL CIRCUIT DESCRIPTION — The voltmeter employs a resistance-capacitance decade attenuator, a high-gain three stage negative feedback stabilized amplifier, a rectifier and a logarithmic indicating meter responding to the average values of the voltage wave but calibrated in rms values of a sine wave. Wire-wound resistors are used in the attenuator so as to insure a degree of stability otherwise unobtainable. The amplifier has sufficient feedback to render the indications of the voltmeter substantially independent of changes in line voltage, tubes, and other circuit components.

OPERATION — The voltmeter is supplied with tubes and is ready to operate as received. It is merely necessary to connect it to the ac power source and turn on the switch marked "ON-OFF." A pilot light is provided to indicate when power is on. The input terminal marked "GND" is connected to the case of the instrument and therefore, whenever possible, it should be connected to the ground of the circuit in which a voltage is being measured.

INPUT IMPEDANCE — The input impedance of the voltmeter 500,000 ohms shunted by a capacitance of 30 $\mu\mu$f.

If a higher input impedance is desired and if it is not necessary to ad less than 10 millivolts, the input impedance may be increased 5 megohms shunted by 8 $\mu\mu$f by using the Ballantine Model 300A Multiplier ahead of the voltmeter. If it is not necessary to read ss than 100 millivolts, the input impedance may be increased to 0 megohms shunted by 3 $\mu\mu$f by using the Ballantine Model 300B Multiplier ahead of the voltmeter.

Any direct current component of the wave under measurement is olated from the voltmeter by means of a series input blocking ca- acitor of 400 volts rating. If dc voltages higher than this are applied n auxiliary protective network should be provided consisting of a μf capacitor in series with the connection to the high potential nput terminal and a 1 megohm resistor in shunt with the input erminals. An example of the use of such a network would be the neasurement of commutator ripple on a 600-volt dynamotor.

OVERLOAD CHARACTERISTICS — The amplifier circuits are esigned to saturate promptly when the voltage exceeds the full cale indication of the meter, thus protecting the indicating meter. his is a considerable advantage over other types of meters which nay be seriously damaged by overloads such as the Model 300 Volt- neter will stand. The maximum voltage which can be safely toler- ted on each range for an indefinite period is as follows:

Range	Max. Voltage	Overload Ratio
.001 - .01	2	200
.01 - .1	20	200
.1 - 1	200	200
1 - 10	400	40
10 - 100	400	4

EFFECT OF WAVE FORM — The indications of the volt- neter are proportional to the average value of the ac wave under neasurement. Since, however, it is primarily intended to measure inusoidal waves its calibration is in terms of the rms value of a inusoidal wave. Since electronic voltmeters of the input diode rectifier

type respond to the peak values of a wave, the readings of such meters and the present voltmeter will not necessarily agree when harmonics are present. The amount of the discrepancy will depend on the number and magnitude of the harmonics present as well as their phase relationship with respect to the fundamental. In all cases however, the departure of the readings from true rms values due to the presence of harmonics will be considerably less with an average responding meter such as the Model 300 than with a peak responding meter. For example in the case of a third harmonic whose amplitude is 20% of the fundamental the maximum error of a peak responding meter may be as much as 20% whereas the maximum error of an average responding meter such as the Model 300 will never exceed 0.7%.

Inasmuch as the Model 300 Voltmeter responds to the average value of the ac wave, "turn-over" discrepancies occasioned by any lack of symmetry of the wave such as are experienced in half-wave peak reading instruments are eliminated, provided the crest factor of the wave does not exceed 2 when readings are being made at full scale. For lower readings the crest factor limit is increased in inverse proportion to the ratio of the reading and full scale deflection.

MEASUREMENT OF LINE FREQUENCY VOLTAGES

Even though the amount of residual hum in the voltmeter is extremely small, it may introduce slight inaccuracies (1 to 2%) in the readings at the lower end of the scale when the voltmeter is used to measure voltages having exactly the same frequency as that of the power supply mains. These inaccuracies may be minimized by making two measurements, one with the power plug in normal polarity and the other with the power plug reversed. The mean of these readings will represent the true value of the voltage being measured.

MEASUREMENT OF VOLTAGES ABOVE 100 VOLTS — Multipliers are available from Ballantine Laboratories, Inc., to extend the range of the voltmeter to voltages above 100. The Model 1300A Multiplier extends the range by a factor of 10 up to 1,000 volts maximum. This has an input impedance of 5 megohms shunted by 8 $\mu\mu$f. The Model 1300B Multiplier extends the range by a factor of 100 to 10,000 volts and has an input impedance of 40 megohms shunted by 3 $\mu\mu$f.

These multipliers cover the same frequency range as the Model 300 voltmeter.

MEASUREMENT OF VOLTAGES BELOW ONE MILLIVOLT — When voltages below one millivolt are to be measured it is recommended the use of the Ballantine battery operated Decade Amplifier, Model 220-B. This provides gains of exactly ten times or one hundred times and when connected ahead of the Model 300 Voltmeter permits measurements down to values as low as 20 microvolts in the frequency range from 10 cps to 150 kc.

MEASUREMENT OF POWER LEVELS — In view of the many different applications for Ballantine Voltmeters and the prevailing differences in power reference levels, it was felt inadvisable to relate the db scale to a particular level in the standard version of the Model 300. Accordingly, in the interest of clarity and generality, the 0 of the db scale has been set arbitrarily at 1 on the voltage scale, and 20 db, therefor, corresponds to 10 on the voltage scale (A special version, Model 300-S/5, is available however with the db scale arranged for zero at 1 mw/600Ω).

The most frequently used power references at which a level of zero decibels is arbitrarily set are:

(1) 1 mw/600 Ω — 1 milliwatt of power corresponding to 0.775 volts across a pure resistance of 600 ohms.

(2) 6 mw/600 Ω — 6 milliwatts of power corresponding to 1.897 volts across a pure resistance of 600 ohms.

(3) 6 mw/500 Ω — 6 milliwatts of power corresponding to 1.732 volts across a pure resistance of 500 ohms.

The following table enables a ready conversion from the db reading of the Ballantine Scale to the actual zero db power level for any of the reference levels above including zero db corresponding to 1 volt.

For power reference levels other than those above are involved the Ballantine Laboratories, Inc., DB Slide Rule will be found very useful for the corresponding decibel level determinations. The slide rules are available free of charge on application to the Company.

MODEL 300 RANGE SETTING	DB TO BE ADDED TO OR SUBTRACTED FROM THE DB READING ON THE BALLANTINE DB SCALE IN ORDER TO CONVERT TO THE DESIRED ZERO REFERENCE LEVEL			
Volts Full Scale	[illegible]	[illegible]	Zero Level [illegible]	[illegible] Level
0.01	−57.8	−65.6	−64.8	−60
0.1	−37.8	−45.6	−44.8	−40
1.0	−17.8	−25.6	−24.8	−20
10.0	+ 2.2	− 5.6	− 4.8	0
100.0	+22.2	+14.4	+15.2	+20

USE AS AN AMPLIFIER Inserting a standard tip and sleeve telephone plug into the output jack marked "AC OUTPUT" automatically disconnects the rectifier and the indicating meter and permits the amplifier section of the voltmeter to be used as a stable amplifier with a maximum gain of 70 db. The gain is adjustable in steps of 20 db by means of the range switch and finer adjustments in gain may be made by means of the knob marked "AC OUTPUT CONTROL." When the latter is set for maximum gain the output impedance of the amplifier is approximately 15,000 ohms. The amplifier will provide uniform voltage amplification within 1 db over the range from 10 to 150,000 cps when loaded by a resistance of not less than one megohm and a capacitance (including that of the telephone plug) of not more than 30 $\mu\mu$f. The hum and noise level present at the output jack when the instrument is used as an amplifier is less than 50 millivolts which is 55 db down from its maximum undistorted output voltage level of 30 volts. This hum and noise level is equivalent to less than 10 microvolts when referred to the input.

PROVISION OF DC OUTPUT – A useful and compact accessory, the Model 2300 DC Output Adapter, is available from Ballantine Laboratories and is designed to plug into the "AC OUTPUT" jack of the voltmeter thus allowing it to drive external strip-chart recorders, remote meters, or any other external device requiring up to 2 milli-

[illegible] for [illegible] operation. Such [illegible] [illegible] corresponding to any voltage covered by the Voltmeter [illegible] [illegible] 30 to 150,000 cps.

[illegible] is made for calibrating the DC output of the Model 2300 [illegible] against the voltmeter readings by means of an accessible control.

The [illegible] binding posts are isolated from ground so as to leave the [illegible] option of grounding either the positive or negative leg or of [illegible] both terminals floating.

USE AS A MICROAMMETER-AMMETER – By using Ballantine [illegible] Precision Shunt Resistors in conjunction with the Voltmeter [illegible] currents from 1 microampere to 1 ampere can be measured [illegible] the frequency range 10 to 150,000 cps, and to 10 amperes over the [illegible] 10 to 20,000 cps.

MEASUREMENT OF DIRECT VOLTAGES – Ballantine Laboratories manufactures an instrument known as the Model 700 Precision [illegible] Inverter which, although it has multifarious applications elsewhere, may be combined with the Model 300 Voltmeter to measure DC potentials from 100 volts down to as low as 10 microvolts with an input resistance of 50 megohms down to 100 millivolts and 10 megohms below.

Among the many features of the Model 700 Inverter are means for polarity sensing, extremely small zero drift, and a built-in device for calibrating the Inverter-Voltmeter combination so that a high degree of accuracy is realized under the most onerous operating conditions.

SCALE RANGE ADJUSTMENT – When the scale range adjustment is properly set a voltage input which produces a scale reading of 10 will produce a scale reading of 1 on the next higher range. No [illegible] need be given to this adjustment except at very infrequent [illegible] intervals, but if some discrepancy is noted the required change in the adjustment should be made as follows: Allow the meter to warm up for five minutes. Connect a source of pure sinusoidal ac of any convenient frequency from 100 to 10,000 cps to the input. Adjust this voltage so that the meter reads 10 on any range other than the 100 volt range. Switch to the next higher range. The meter should read 1. If not, remove the black button at the side of the case and adjust the [illegible] control with a screw-driver until the meter reads 1. Switch back to the lower range and check to see that it reads 10. If not, adjust the input voltage to 10 and switch back to 1, readjusting the [illegible] screw-driver if necessary.

In the past [illegible] the purpose of this adjustment [illegible] setting the needle on the meter to [illegible] with no voltage applied to the input terminals. The indicating meter, being galvanometric, has no "zero." The normal position of the needle with no voltage applied to the input is against the left-hand stop and off scale. The meter should read only when a voltage within the range of the voltmeter is applied to its input terminals.

SERVICING – Servicing of this instrument by the user is not recommended except for scale range adjustment described on page 8 and except for the renewal of the fuse, pilot light, and tubes. If trouble develops which cannot be corrected by following these instructions, it is recommended that the instrument be returned to us for servicing. **Before returning the instrument please describe the trouble to us by letter** and we shall furnish shipping instructions.

The failure of the pilot light to light after the switch is turned on is an indication of either a blown fuse or a burned-out pilot light. The pilot light may be replaced from the front of the panel by merely unscrewing the red jewel. A three-quarter ampere fuse is mounted on the chassis inside the case. To renew the fuse first disconnect the instrument from the ac power line and after removing the four nickel-plated screws on the panel carefully lift out the panel from the case. The fuse clip is situated alongside the power transformer.

Spare fuses are provided and if additional fuses are required these may be ordered directly from Littelfuse, Inc., 4757 Ravenswood Avenue, Chicago, Illinois. The type number is 8AG, three-quarter ampere.

SPECIAL VERSIONS OF THE MODEL 300 VOLTMETER

Although the basic Model 300 Voltmeter used either by itself or in conjunction with its various accessories is a most versatile instrument a number of special versions or modifications of the voltmeter have been created to meet the particular preferences of various industrial and scientific organizations. These special instruments are tabulated below and application should be made to Ballantine Laboratories regarding prices and delivery.

Ballantine Laboratories Inc., is always ready to consider requests for new custom-built variants of the Model 300 Voltmeter or of any of its other standard products and usually special needs can be satisfied at only a nominal increase in price above that of the basic Model.

Model No.	DESCRIPTION
300-S/1	Similar to basic Model 300 but having one megohm input impedance (3% accuracy).
300-S/2	Similar to basic Model 300 but mounted on a 19" x 7" x $\frac{1}{8}$" relay rack panel.
300-S/4	Similar to basic Model 300 but covering a voltage range of 2 millivolts to 200 volts.
300-S/5	Similar to basic Model 300 but with the db scale referred to 1 milliwatt in 600 ohms. Range switch marked in db's as well as volts.
300-S/7	A combination of the Model 300-S/1 and Model 300-S/2 deviations from the basic Model 300.
300-S/10	A combination of the Model 300-S/2 and Model 300-S/5 deviations from the basic Model 300.

ALLANTIN[illegible] LABORATORIES, INC.

REFERENCE LIST OF PARTS

...FER TO MODEL 300 SCHEMATIC DIAGRAM MC-1071.

Symbol	RESISTORS	Manufacturer
[illegible]	3 megohms, Type EB, 10%	Allen-Bradley
[illegible]	51,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	450,000 ohms, Type P51, ½%	Shalleross
[illegible]	45,000 ohms, Type P51, ½%	Shalleross
[illegible]	4,500 ohms, Type P12, ½%	Shalleross
[illegible]	450 ohms, Type P12, ½%	Shalleross
[illegible]	50 ohms, Type P12, ½%	Shalleross
[illegible]	2,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	4.3 ohms, Special	Ballantine
[illegible]	20,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	50,000 ohms, Type M161, 1%	Mepco
[illegible]	300,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	20,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	2,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	100,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	47,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	470,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	20,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	390 ohms, Type EB, 5%	Allen-Bradley
[illegible]	47,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	38,000 ohms, Type P34, 1%	Shalleross
[illegible]	50,000 ohms, Type M161, 1%	Mepco
[illegible]	2,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	100,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	2,000,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	20,000 ohms, Type Q Volume Control	I.R.C.
[illegible]	25,000 ohms, Type Q Volume Control	I.R.C.
[illegible]	4,700 ohms, Type BW-2, 5%	I.R.C.
[illegible]	27,000 ohms, Type 28E, 5%	Sprague
[illegible]	4,700 ohms, Type BW-2, 5%	I.R.C.
[illegible]	20,000 ohms, Type GB, 5%	Allen-Bradley
[illegible]	62,000 ohms, Type GB, 5%	Allen-Bradley
[illegible]	160 ohms, Type EB, 5%	Allen-Bradley
[illegible]	150,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	2,000,000 ohms, Type EB, 5%	Allen-Bradley
[illegible]	300 ohms, Type EB, 5%	Allen-Bradley

• The values of these items are determined during the calibration of the instrument and may differ from the value listed.

BALLANTINE LABORATORIES, INC.

REFERENCE LIST OF PARTS

REFER TO MODEL 300 SCHEMATIC DIAGRAM MC-197L

B. L. Part #	Circuit Symbol	CONDENSERS	Manufacturer
2145	C1	.1 μF, 400 volts, Type 109P10494	Sprague
2458	C2	25 pF, maximum, Type 823-Z	Centralab
2000	C3	4.7 pF, Type GA-6	Stackpole
2451	C4	3-12 pF, maximum, Type 503-27	Erie
2215	**C5	.015 μF, mica +0 -10%, Type CM35B153J	Arco
2210	C6	.001 μF, mica, 5%, Type CM30	Arco
2407	C7	550-1600 pF, No. X309	El-Menco
2405	C8	65-340 pF, No. X303	El-Menco
2407	C9	550-1600 pF, No. X309	El-Menco
2001	C10	2 pF, Type CM15C-020-M	Arco
2055	C11	25 μF, 25 volts, Type DPE	Sprague
2003	C12	20 μF, 250 volts, Type DEE	Sprague
2003	C13	20 μF, 250 volts, Type DEE	Sprague
2142	C14	.1 μF, 200 volts, Type 109P10492	Sprague
2055	C15	25 μF, 25 volts, Type DPE	Sprague
2003	C16	20 μF, 250 volts, Type DEE	Sprague
2003	C17	20 μF, 250 volts, Type DEE	Sprague
2145	C18	.1 μF, 400 volts, Type 109P10494	Sprague
2055	C19	25 μF, 25 volts, Type DPE	Sprague
2003	C20	20 μF, 250 volts, Type DEE	Sprague
2366	C21	.5 μF, 400 volts, PUP	Cornell-Dubilier
2015	**C22	5 pF, Type GP1K	Erie
2055	C23	25 μF, 25 volts, Type DPE	Sprague
2160	C24	2 μF, 600 volts, Type 7160-2	Sangamo
2061	C25	8 μF, 450 volts, Type DEE	Sprague
2051	C26	8 μF, 450 volts, Type DEE	Sprague

TUBES

3102	V-1	- One Type 6J7 or 1620, RCA or equal
3103	V-2	- One Type 6SJ7, RCA or equal
3103	V-3	
3104	V-4	- One Type 6AL5, RCA or equal
3100	V-5	- One Type 6X5, RCA or equal
3101	V-6	- One Type OA2, RCA or equal
3451		- One pilot light, 6.3 volts, .150 amp, bayonet

** The values of these items are determined during the calibration of the instrument and may differ from the value listed.

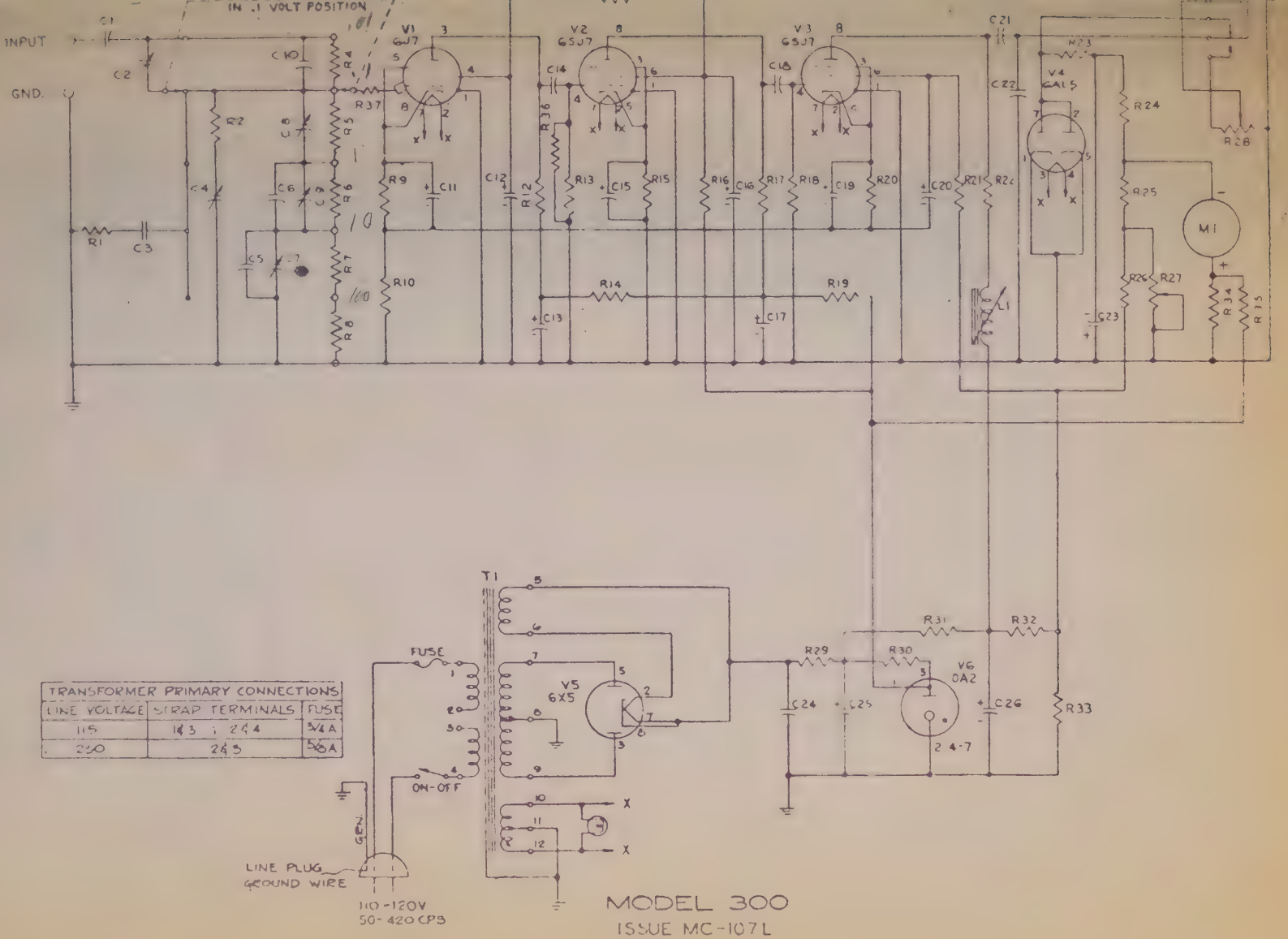
METER

3151	M-1	- Special type obtained from Ballantine Laboratories, Inc. only
3405	Fuse	- 3/8 ampere, Type 8-AG, Littelfuse Inc., Type 362.375 or equal

TRANSFORMER

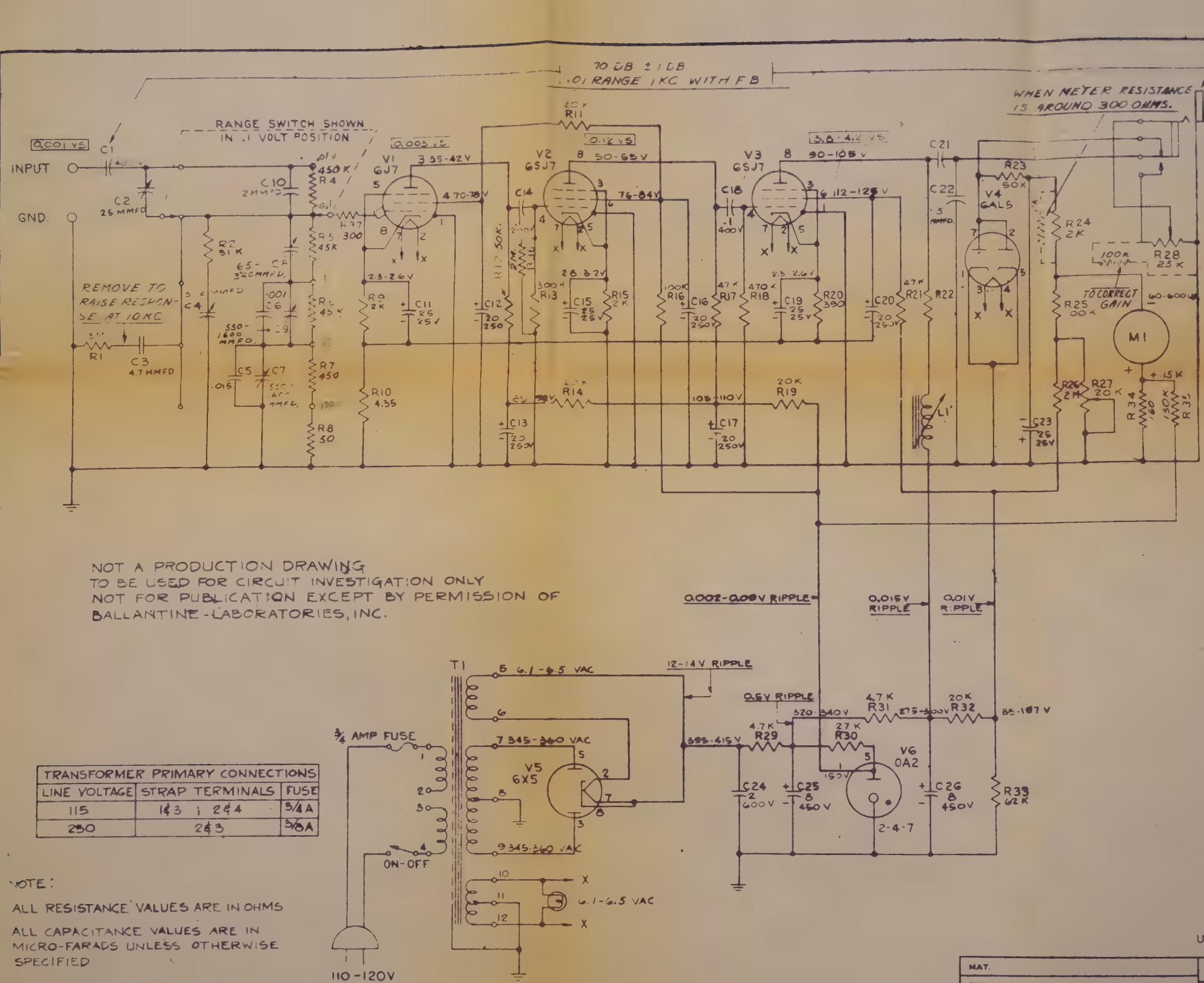
3027	T-1	- Type A-326F below Serial #21157, Ballantine Laboratories, Inc.
3040		- Type MB-521A above Serial #21157, Ballantine Laboratories, Inc.
3003	L-1	- Peaking Coil, Ballantine Laboratories, Inc.

3-14-60



TRANSFORMER PRIMARY CONNECTIONS		
LINE VOLTAGE	STRAP TERMINALS	FUSE
115	1&3 ; 2&4	3/4 A
230	2&3	3/8 A

MODEL 300
ISSUE MC-107L



NOTES:

1. LINE VOLTAGE IS 115V FOR ALL MEASUREMENTS
2. INPUT TERMINALS SHORT CIRCUITED & RANGE SWITCH SET TO "100V" ON ALL DC & RIPPLE VOLTAGE MEASUREMENTS
3. ALL DC VOLTAGE MEASUREMENTS MADE WITH RCA VOLTOHMYST 11 MEGOHMS INPUT RESISTANCE
4. ALL AC MEASUREMENTS UNDER 100V MADE WITH BALLANTINE MODEL 300
5. ALL AC MEASUREMENTS OVER 100V MADE WITH RCA VOLTOHMYST
6. VOLTAGES IN BOXES & DESIGNATED VS ARE SIGNAL VOLTAGES MADE AT 1000 CPS ON THE 0.1V RANGE, WITH R10 SHORT CIRCUITED (NO FEEDBACK)
7. FEEDBACK CHECK: WITH AN INPUT VOLTAGE OF 0.001 V, 1000 CPS, ON THE 0.01 V RANGE SHORT CIRCUIT R10. THE INCREASE IN INDICATION SHOULD BE 20 db MIN. SWITCH TO 0.1V RANGE IF NECESSARY TO READ INCREASE)
8. HUM & NOISE CHECK: A. INPUT TERMINALS SHORT CIRCUITED - 30 MV MAX. ALL RANGES B. INPUT TERMINALS OPEN CIRCUIT & SHIELDED - 50 MV MAX ALL RANGES. MEASUREMENTS MADE WITH BALLANTINE MODEL 300 WITH OUTPUT CABLE AND PLUG CAPACITANCE = 50 MMFD; R28 SET FOR MAX OUTPUT

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TRANSFORMER PRIMARY CONNECTIONS		
LINE VOLTAGE	STRAP TERMINALS	FUSE
115	1&3 ; 2&4	3/4 A
250	2&3	3/8 A

NOTE:

ALL RESISTANCE VALUES ARE IN OHMS

ALL CAPACITANCE VALUES ARE IN MICRO-FARADS UNLESS OTHERWISE SPECIFIED

USED ON: 300, 300 S/2

MODEL 300

MAT.					
FIN.					
ISSUE	DATE	CHANGE	ISSUE	DATE	CHANGE
B	DEC 56				
C	2-25-57				
M	DEC 57				

UNLESS OTHERWISE SPECIFIED DECIMAL DIMENSIONS ± .005", FRACTIONAL DIMENSIONS ± 1/64

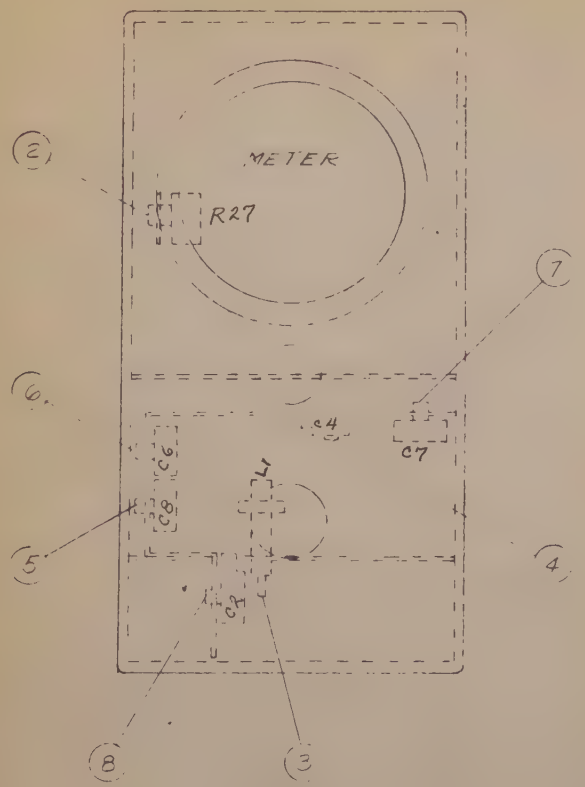
SERVICE SCHEMATIC

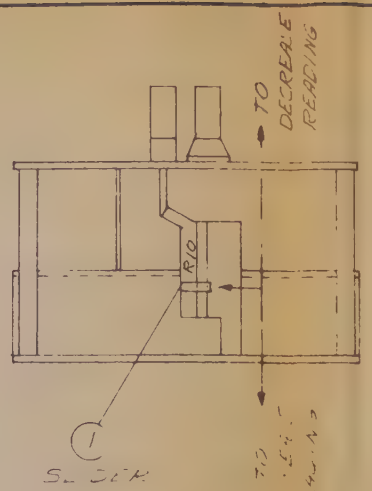
BALLANTINE LABORATORIES, INC. BOONTON, N. J.

DRAWN RET 3-17-55 | SCALE

APPVD. [illegible] | USED ON SEE NOTE

DWG. NO. DC-292 C





NOTE:
USE SCHEMATIC MC-107M AND HIGHER ISSUES.

SEQUENCE OF CALIBRATION ADJUSTMENTS ON MODEL 300

1. FEEDBACK RESISTOR (R-10) ABSOLUTE ACCURACY ADJUSTMENT AT FULL SCALE ON METER AT (1 KC) AND LOWER FREQUENCIES.
2. POT. (R 27) OVERLAP ADJUSTMENT AT (1) ON METER SCALE. 1 KC. AND LOWER FREQUENCIES (SEE INSTRUCTION BOOK).
3. PEAKING COIL ADJUSTMENT (L-1) ON .01 V. RANGE FOR BEST RESPONSE BETWEEN 50 KC - 150 KC.
4. TRIMMER (C-4) ADJUSTED FOR BEST RESPONSE AT 70 KC. ON .1V. RANGE.
5. TRIMMER (C-8) ADJUSTED FOR BEST RESPONSE AT 150 KC. ON .1V. RANGE.
6. TRIMMER (C-6) ADJUSTED FOR BEST RESPONSE BETWEEN 50 KC. TO 150 KC. ON 1V. RANGE.
7. TRIMMER (C-7) ADJUSTED FOR BEST RESPONSE BETWEEN 50 KC. TO 150 KC. ON 10 V. AND 100 V. RANGE.
8. DO NOT ADJUST

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SERIAL NO. 27000 UP

MAT.					
FIN.					
ISSUE	DATE	CHANGE	ISSUE	DATE	CHANGE
A					
M	[illegible] 60				

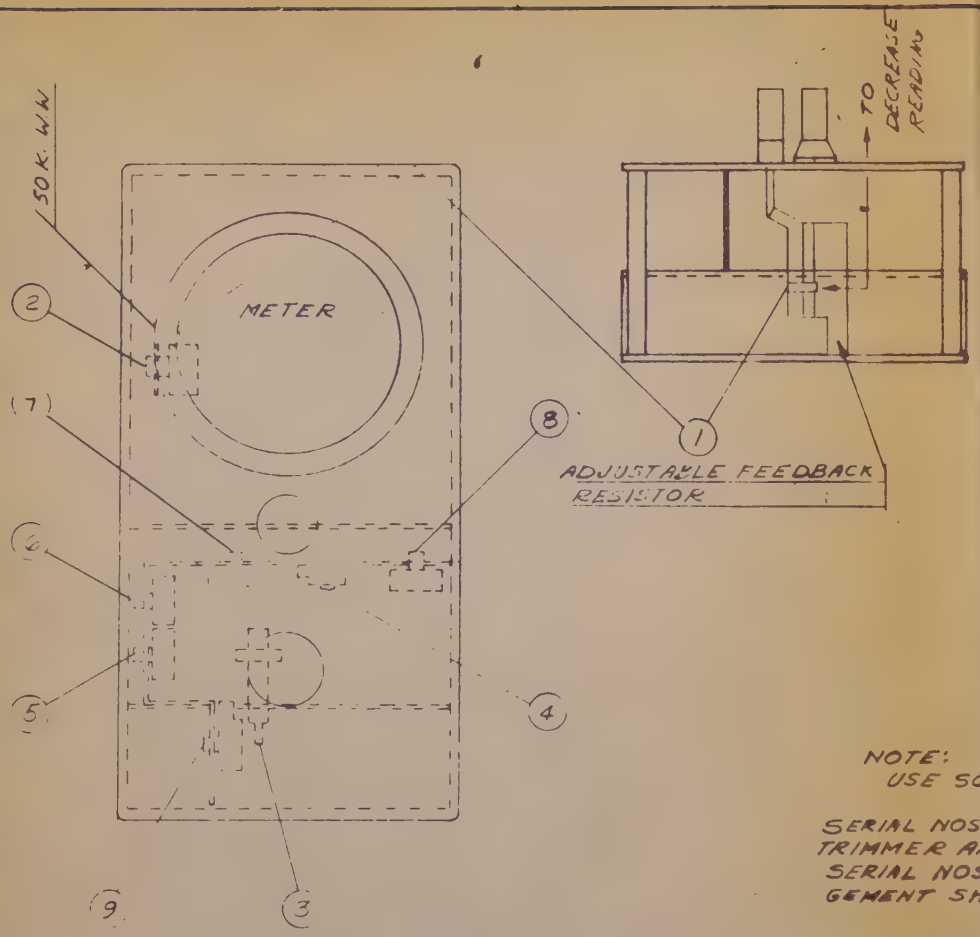
UNLESS OTHERWISE SPECIFIED DECIMAL DIMENSIONS ± .005", FRACTIONAL DIMENSIONS ± 1/64"

CALIBRATION ADJ. DIAGRAM

BALLANTINE LABORATORIES, INC.
BOONTON, N. J.

DRAWN J.F.D. 2-19-58	SCALE
APPVD.	USED ON 300

DWG. NO. DB-403 A



INITIAL ADJUSTMENT.

9. TRIMMER (C-2 OR 120) DO NOT ADJUST

NOTE

SETS NUMBERED 14150 AND BELOW ARE NOT EQUIPPED WITH COIL (L-1). NO HIGH FREQUENCY ADJUSTMENT SHOULD BE NECESSARY ON THESE SETS ON .01V. RANGE.

NOTE:
USE SCHEMATIC MC-107A TOG

SERIAL NOS. ABOVE 12,000 HAVE THE TRIMMER ARRANGEMENT SHOWN
SERIAL NOS. ABOVE 14150 HAVE ARRANGEMENT SHOWN, PLUS PEAKING COIL

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SEQUENCE OF CALIBRATION ADJUSTMENTS ON MODEL 300.

1. IF NOT USED, ABSOLUTE ACCURACY MAY BE INCREASED BY SHUNTING 50K WW DIODE RESISTOR WITH CARBON RESISTOR (750 K. TO 2 MEG.)
2. POT. (R-24-27) OVERLAP ADJUSTMENT AT (1) ON METER SCALE. (INC. AND LOWER FREQUENCIES (SEE INSTRUCTION BOOK).
3. PEAKING COIL ADJUSTMENT (L-1) ON .01 V. RANGE FOR BEST RESPONSE BETWEEN 50 KC - 150 KC.
4. TRIMMER (C-4-100) ADJUSTED FOR BEST RESPONSE AT 70 KC. ON .1V. RANGE.
5. TRIMMER (C-8-101) ADJUSTED FOR BEST RESPONSE AT 150 KC. ON .1V. RANGE.
6. TRIMMER (C-9-102) ADJUSTED FOR BEST RESPONSE BETWEEN 50 KC. TO 150 KC. ON 1V. RANGE.
7. TRIMMER (C-7-103) ADJUSTED FOR BEST RESPONSE BETWEEN 50 KC. TO 150 KC. ON 10V. RANGE.
8. TRIMMER (C-10 OR C-103) ADJUSTED FOR BEST RESPONSE BETWEEN 50 KC. TO 150 KC ON 100V. RANGE

NOTE: ADJUSTMENTS 7 & 8 ARE NOT INDEPENDENT OF ONE ANOTHER AND READJUSTMENT MAY BE NECESSARY ON BOTH TRIMMERS AFTER

MAT
FIN.

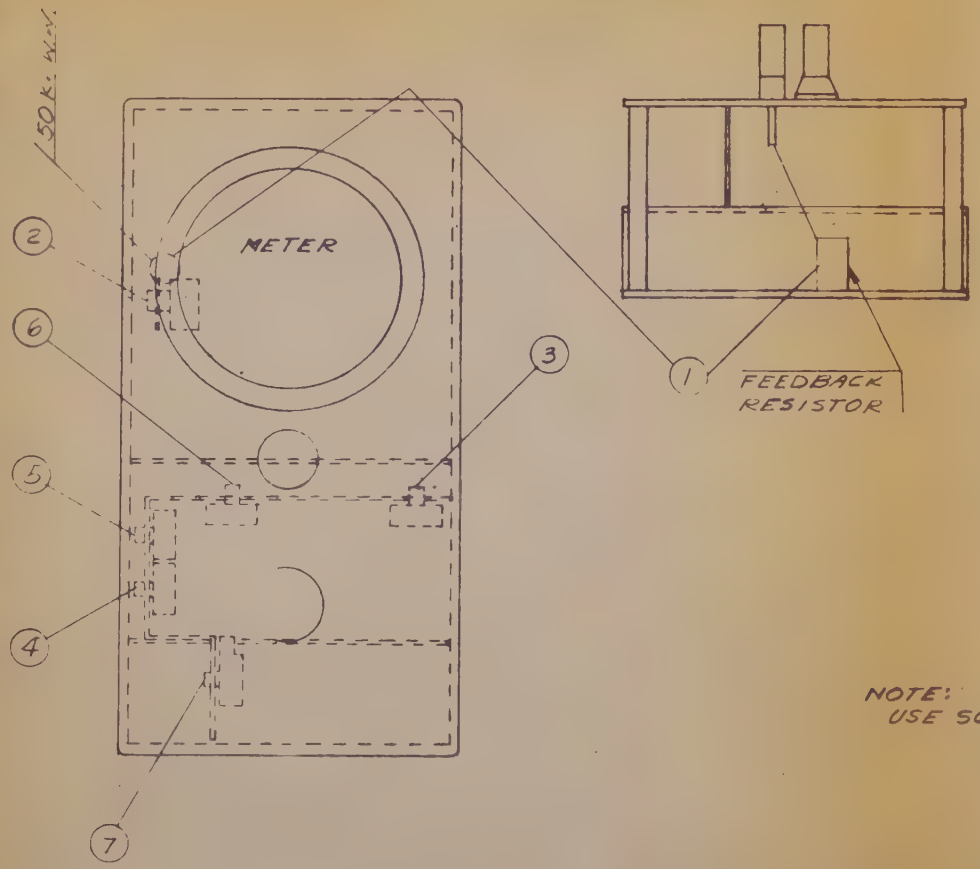
ISSUE	DATE	CHANGE	ISSUE	DATE	CHANGE
A	JAN. 60				

CALIBRATION ADJ. DIAGRAM

BALLANTINE LABORATORIES, INC.
BOONTON, N. J.

DRAWN J.F.D. 2-19-58	SCALE
APPVD.	USED ON 300

DWG. NO. DB-404A



NOTE:
USE SCHEMATIC MB-100A

SEQUENCE OF CALIBRATION ADJUSTMENTS ON MODEL 300

1. ABSOLUTE ACCURACY MAY BE INCREASED BY SHUNTING 50 K. W.W. DIODE RESISTOR WITH CARBON RESISTOR (250 K. TO 2 MEG.)
2. POT. (R84) OVERLAP ADJUSTMENT AT (1) ON METER SCALE. 1 KC. AND LOWER FREQUENCIES (SEE INSTRUCTION BOOK).
3. TRIMMER (100) ADJUSTED FOR BEST RESPONSE AT 150 KC. ON .1V. RANGE.
4. TRIMMER (101) ADJUSTED FOR BEST RESPONSE AT 150 KC. ON 1V. RANGE.
5. TRIMMER (102) ADJUSTED FOR BEST RESPONSE BETWEEN 50 KC. TO 150 KC. ON 10V. RANGE.
6. TRIMMER (103) ADJUSTED FOR BEST RESPONSE BETWEEN 50 KC. TO 150 KC. ON 100 V. RANGE
7. TRIMMER (120) DO NOT ADJUST.

NOT A PRODUCTION DRAWING
TO BE USED FOR CALIBRATION ADJUSTMENTS ONLY.
NOT FOR PUBLICATION EXCEPT BY PERMISSION OF BALLANTINE LABORATORIES INC.

SERIAL NO. 12000 BELOW

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A	M JAN. 60				

UNLESS OTHERWISE SPECIFIED DECIMAL DIMENSIONS ± .005", FRACTIONAL DIMENSIONS ± 1/64"

CALIBRATION ADJ. DIAGRAM

BALLANTINE LABORATORIES, INC.
BOONTON, N. J.

DRAWN J.F.D. 2-19-58 | SCALE
APPVD. | USED ON 300

DWG. NO. DB-405 A

INSTRUCTION BOOK

for

MODEL 320A
TRUE ROOT MEAN SQUARE
ELECTRONIC VOLTMETER

BALLANTINE LABORATORIES, INC.

BOONTON, NEW JERSEY

ARL A. STONE ASSOCIATES, INC.

representing electronics manufacturers

[redacted] • [redacted] • UPton 0-7771 TWX: Cvr Cy 4146

ardiff Avenue, Culver City, California

September 30, 1963

MR. WILL HONDA
Department A2
Douglas Aircraft Company
3000 Ocean Park Boulevard
Santa Monica, California

Subject: Ballantine Laboratories, Inc.
Model 320A-U/12 Special Voltmeter

Dear Mr. Honda:

In accordance with your request, Ballantine Laboratories has advised us that they can lower the slide panel of the Model 320A-U/12 so that the distance will be 3.50" from the bottom of the panel to center of slide. Outline Drawing No. DD-1029 B is attached showing this change.

The cost of $677.00 and delivery of sixty days after receipt of order will not be affected by this change.

Very truly yours,

CARL A. STONE ASSOCIATES, INC.

Clyde Blyleven

Clyde Blyleven

CB:nd

Enclosure

CARL A. STONE ASSOCIATES, INC.

representing electronics manufacturers

[redacted] • [redacted] • UPton 0-7771 TWX: Cvr Cy 4146
Cardiff Avenue, Culver City, California

October 28, 1963

MR. WILL HONDA
Department A2
Douglas Aircraft Company
3000 Ocean Park Boulevard
Santa Monica, California

Subject: Ballantine Laboratories, Inc.
Model 320A-U/12 Special Voltmeter

Dear Mr. Honda:

This is to advise you that the front panel of the Model 320A-U/12 Voltmeter will be painted a semi-gloss grey, Color No. 26440 per FED-STD-595, in accordance with specification TT-E-529, lettering and knobs to be black.

We also wish to advise you that an eight-foot AC power cable will be furnished with this instrument.

We trust that this will give you the desired information..

Very truly yours,

CARL A. STONE ASSOCIATES, INC.

Clyde Blyleven

Clyde Blyleven

CB/nd

WARRANTY

Each Ballantine Laboratories, Inc. instrument, or part thereof, is warranted to be free from defects in material and workmanship. Ballantine Laboratories, Inc. obligation under this warranty is limited to repairing or replacing any instrument or part thereof, except vacuum tubes and batteries, which shall within one year after shipment to the original purchaser prove upon Ballantine Laboratories, Inc. examination to have become defective.

INSTRUCTION BOOK CONTENTS

FOR

MODEL 320A TRUE ROOT MEAN SQUARE

ELECTRONIC VOLTMETER

		Page
1.	**GENERAL INFORMATION**	1
1.1	Purpose and Use	1
1.2	Some Applications of the Model 320A	1
1.3	Technical Characteristics	1
2.	**OPERATION**	2
2.1	Power Connection	2
2.1.1	Line Voltage Conversion	2
2.2	Starting Procedure	2
2.2.1	Warmup Period	3
2.3	Function of Controls	3
2.3.1	Connectors and Terminals	3
2.3.2	Controls	3
2.4	Voltage Measurement	3
2.4.1	Scale Adjustment	3
2.5	Possible Error Sources	4
2.5.1	Pointer Stays Extreme Left	4
2.5.2	Indication is High	4
2.5.3	Pointer Stays Extreme Right	4
2.5.4	Input Impedance and Loading Error	4
2.5.5	Ground Current Error	4
2.5.6	Transmission Line Error	4
2.5.7	Magnetic and Electrostatic Fields	4
2.6	Use of the DB Scale	4
2.7	Effect of Harmonics	5
2.8	Effect of High Crest Factor	5
2.8.1	Flat Top Waveforms	5
2.9	Effect of the DC Component	6
2.10	Measurement of Noise and Random Signals	6
2.11	Measurement of Waveforms with Higher Crest Factor than 5	6
2.12	Measurement on .3 mV Range	7
2.13	Measurement of Voltages Above 300 V	7
2.14	Use as Null Detector	7
2.14.1	To Use the Model 320A as Null Detector	7
2.14.2	For Approximate Voltage Measurements Below 100 μV	7
2.15	Overload Characteristics	7
2.16	Influence of Power Line Voltage	7
2.17	RMS Current Measurements	8
2.18	Power Dissipation Measurement	8
2.19	Use of Mean Square Output	8
2.20	Use as Amplifier	8
3.	**CIRCUIT DESCRIPTION**	9
3.1	Input and Midsection Attenuators	9
3.1.1	Input Attenuator	9
3.1.2	Midsection Attenuator	9

		Page
3.2	Input Amplifier	10
3.3	Output Amplifier	10
3.4	Phase Inverter	10
3.5	Square Law Detector	10
3.6	Power Supply	10
4.	**MAINTENANCE**	10
4.1	General	10
4.2	Recommended Maintenance	11
4.2.1	Meter screw adjustment	11
4.2.2	1,000 Hour Check	11
4.2.3	2,000 Hour Check	11
4.3	Necessary Maintenance Equipment	11
4.3.1	DC Voltmeter	11
4.3.2	Stable AC Voltage Source	11
4.3.3	Calibrated AC Voltage Source	11
4.3.4	Tube Tester	11
4.3.5	Calibrated, Variable RF Voltage Source	11
4.3.6	Variable Metered AC Power Supply	11
4.4	Removal of the Case	11
4.5	Scale Adjustment	11
4.6	1,000 Hour Check	11
4.6.1	Tests Comprising the 1,000 Hour Check	11
4.6.2	Bias Test of V7 Tube	11
4.6.3	Meter Screw Adjustment	11
4.6.4	Line Voltage Stability Test	11
4.6.5	Midband Accuracy Test	11
4.7	2,000 Hour Check	12
4.7.1	Tests Comprising the 2,000 Hour Check	12
4.7.2	Power Supply Test	12
4.7.3	Bias Test on V7	12
4.7.4	Tube Test	12
4.7.5	Frequency Response Test	12
4.7.6	Midband Accuracy Test	13
5.	**SERVICE AND TROUBLESHOOTING**	13
5.1	General	13
5.2	Necessary Equipment	13
5.2.1	DC Voltmeter, Ohmmeter	13
5.2.2	Sensitive DC Voltmeter	13
5.2.3	Sensitive AC Voltmeter	13
5.2.4	Signal Generator	13
5.2.5	Accurate RF Voltage Calibrator	13
5.2.6	Accurate Calibrated 1 kc Voltage Source	13
5.2.7	HF Diode Voltmeter	13
5.3	Simple Service Problems	13
5.3.1	Removal of the Case	13
5.3.2	Pilot Light Replacement	13
5.3.3	Fuse Replacement	13
5.3.4	Tube Replacement	13
5.4	DC Voltage Check	13
5.5	Signal Tracing	14

		Page
5.6	Check of Square Law Detector and Indicator	14
5.6.1	Continuity Test	14
5.6.2	Diode Test	14
5.6.3	Squarer Bias Test	14
5.6.4	Electrical Linearity	15
5.7	Frequency Response Alignment	15
5.7.1	Low Frequency Response	15
5.7.2	High Frequency Response	16
5.7.3	Amplifier Response Alignment	16
5.7.4	0.3 mV Range Adjustment	16
5.7.5	C30 Midsection Attenuator Adjustment	16
5.7.6	C31 Midsection Attenuator Adjustment	17
5.7.7	Input Attenuator Adjustments	17
5.8	Sensitivity Adjustment	18
5.8.1	R71 Sensitivity Adjustment	18
5.8.2	R29 .3 mV Range Sensitivity Adjustment	18
5.9	Table of Calibration Controls	18
5.10	Service of Attenuators	18
5.11	Intrinsic Noise and Hum Test	18
5.12	Service of the Power Supply	18
5.13	Troubleshooting Chart	19
6.	**SHIPPING INSTRUCTIONS**	20
7.	**CALIBRATION TABLE**	21
8.	**REPLACEMENT PARTS LIST**	25

ILLUSTRATIONS AND DIAGRAMS

		Page
Figure 1.	Ballantine Model 320A True RMS Voltmeter	IV
Figure 2.	Rack Panel Mounted Ballantine Model 320A-S. 2 True RMS Voltmeter	IV
Figure 3.	Input Resistance Change with Frequency	4
Figure 4.	Duty Cycle and Crest Factor of a Pulse Train	5
Figure 5.	Connection of the External Blocking Capacitor	6
Figure 6.	Crest Factor Error with White Noise	6
Figure 7.	Use of External Attenuator to Extend the Crest Factor Limit	6
Figure 8.	Calibration of 0.3 mV Range on Null Detector Mode	7
Figure 9.	Simplified Circuit Diagram	9
Figure 10.	Connection of Micropotentiometer	12
Figure 11.	Typical Frequency Response	15
Figure 12.	Connection of HF Transfer Voltmeter	17
Figure 13.	Side View of Model 320A (right) Showing Location of Tubes and Adustments	22
Figure 14.	Side View of Model 320A (left) Showing Location of Tubes and Adustments	23
Figure 15.	Front View of Model 320A (escutcheon plate removed) Showing Location of Adjustments	24
Figure 16.	Schematic of Model 320A True RMS Voltmeter	Rear

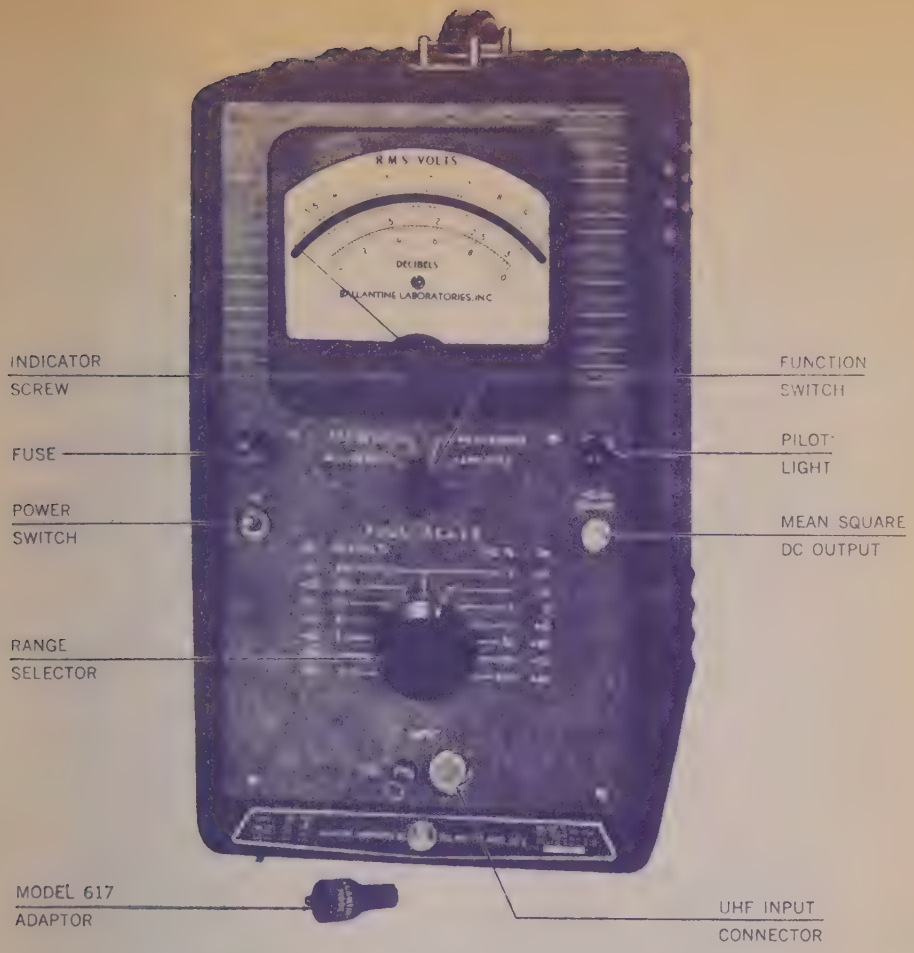


Fig. 1. Ballantine Model 320A True RMS Voltmeter

Fig. 2. Rack Panel Mounted Ballantine Model 320A-S/2 True RMS Voltmeter

1. GENERAL INFORMATION

Purpose and Use

Ballantine Model 320A is a sensitive, wide band, TRUE ROOT MEAN SQUARE responding voltmeter with frequency range of 5 cps to 4 Mc, voltage range of 100 μV to 330 V and a basic accuracy of better than 2%.

Design characteristics — accuracy, band width and maximum crest factor — are chosen so that the instrument is suitable for accurate measurement of a wide variety of complex waveforms which are encountered in current acoustical, vibrational, noise, pulse and magnetic measurements. Besides sinewaves it measures distorted waveforms that include random noise and pulse trains with duty cycles as low as 1% and pulse widths as short as 0.3 μsec.

The true rms response of the Model 320A is achieved by means of the Ballantine patented square law detector which is an accurate, wide band, segmented function generator. In conjunction with a full wave rectifier, this detector provides precise, wide dynamic range, and instantaneous squaring action which is unaffected by the normal range of ambient temperature, overload and component aging. The indication is achieved on two 4.5" long, mirrorbacked, logarithmic scales. *The same precision and accuracy applies to measurements at any point on the scales.* In fact, higher accuracy specification at full scale indication is possible, but it is Ballantine's philosophy that specifying higher accuracy for only certain parts of the scale does not increase the usefulness of the voltmeter. An associated linear db scale with dbv (1 V) as reference is supplied with the standard instrument.

In the design of the voltmeter special consideration is given to operation under disturbing influences. The coaxial type RF input terminal provides a low ground impedance input which reduces the error due to ground currents and allows the use of coaxial input for accurate high frequency measurements. A Model 617 adapter supplied with the voltmeter converts the coaxial input to standard ¾" spacing binding posts, an input preferred for low frequency measurements. The warmup drift is kept small, so that the voltmeter is usable 20 sec after being turned on. The effect of line voltage transients is minimized so that the Model 320A may be used under very unfavorable line conditions.

Besides the excellent initial performance, great emphasis is placed on the reliability and life of the voltmeter. Because of the conservative rating of tubes and components, proper amount of feedback and the reserve in accuracy specifications, it is expected that the great majority of voltmeters will meet its specifications over 5,000 hours of normal laboratory use without the need for readjustments or recalibration. The voltmeter design is such that whenever a tube change may be necessary it does not influence the voltmeter performance over most of the useful band and does not require extensive recalibration or adjustment. The Model 320A stability against line voltage changes is such that the 10% voltage variation from 105 to 125 V will not set the instrument out of specifications. These features make the Model 320A a very economical instrument with respect to service and upkeep which, considering its low initial cost, is more to the value of the voltmeter.

Beyond its basic function as a voltmeter, the Model 320A may be used as a null detector with a sensitivity down to 10 μV. It also can be used as a wide band amplifier with floating, grounded or symmetrical output. Up to 50 V rms may be obtained from the amplifier output. A dc current proportional to the mean square value of input voltage may be obtained, to drive a recorder or other readout device. By means of Ballantine series 600 calibrated shunts, the Model 320A may be converted to a true rms responding ammeter with sensitivity down to 0.1 μA.

The construction of the voltmeter uses high grade printed wiring boards which guarantee uniformity and easy serviceability of the instrument. Modern frame grid tubes with highest grade components are used throughout the circuit. The design is based on 7 years experience with the Ballantine Model 320 — an accepted standard of rms voltmeters throughout the industry.

The Model 320A is available in portable or rack mounted version for 115 V or 230 V, 50 to 420 cps power line.

1.2 Some Applications of the Model 320A

General rms voltage measurement in grounded circuits

Noise figure determination of tubes, transistors, networks and resistors

True rms vibration measurements, in conjunction with vibration pickup

White noise tests of audio equipment and noise level checks in wide band carrier and video systems

Mean square sound pressure measurement and acoustic studies with suitable microphones

As audio output power meter with appropriate load impedance

Measurement of total harmonic distortion in conjunction with a fundamental suppression filter

1.3 Technical Characteristics

Voltage Range	0.1 mV to 330 V in 13 ranges 10 μV sensitivity as null detector
Frequency Range	5 cps to 4 Mc
Waveforms	Sine, complex, pulse or random
Max Crest Factor	15 for down scale indication 5 for full scale indication

Accuracy at ANY Point on the Scale

Sine, complex, and random waveforms

For voltages above 0.3 mV

20 cps to 400 kc	± 2% of indication
10 cps to 2 Mc	± 3% of indication
5 cps to 4 Mc	± 4% of indication

For voltages from 0.1 mV to 0.3 mV

10 cps to 2 Mc	± 4%
5 cps to 4 Mc	± 5% at full scale ± 7% at down scale

Pulse trains and flat top waveforms

Crest factor below 4 (FS) to 10 (DS)
as above
Crest factor below 5 (FS) to 15 (DS)
2% additional uncertainty

ules

0.95 to 3.3, logarithmic
3.0 to 10.6, logarithmic
separated with mirror

0 - 10 db linear

Range —80 to +40 db referred to 1 V

ut Impedance

1 μV to 10 mV range 10 MΩ parallel with 27 pF
0.3 V to 300 V range 10 MΩ parallel with 11 pF

uivalent Input Noise

20 μV max
40 μV max

ponse Time

rmup Time

20 sec

bient Temperature Effect

25°C
less than 1/10 of stated accuracy over 20°C to 30°C

bility

5000 operating hrs
1000 operating hrs
minor effect above
1 Mc only

Amplifier Characteristics

Output	Binding posts in rear, balanced or single ended
Max gain	90 db ± 1 db adjustable in 10 db steps with range selector
Max output	50 V into 20,000 ohms 10 V into 2,000 ohms
Source impedance	350 Ω at 1 kc
Frequency response	+ 0.5 db from 5 cps to 2 Mc — 1 db at 4 Mc, 25 pF max loading

Mean Square Output

Output voltage	0.2 V for full scale deflection
Max output	1.0 V
Source resistance	1,000 Ω

Power Requirements

Voltage	105 to 125 V (210 to 250 V)
Frequency	50 cps to 420 cps
Power consumption	90 W
Fuse	115 V — 0.8 A Slo-blo 230 V — 0.5 A Slo-blo
Effect of line voltage change	± 10 V (± 20 V) line voltage change affects the sensitivity by less than 1/10 of guaranteed accuracy

Vacuum Tubes and Semiconductors

Tubes	2 — 5654 1 — 12BA4A 1 — 5V4G 4 — 6EJ7 1 — OA2 1 — 8223 or 1 — 6DJ8 1 — OB2
Semiconductors	10 — germanium diodes 1 — silicon diode 2 — silicon rectifiers

Mechanical Specifications

Color	Portable Gray panel, black wrinkle case Rack Gray or special to customer's specification
Dimensions	Portable 15¼" H x 8⅝" W x 11¼" D Rack 8 23/32" H x 19" W x 12¼" D
Weight	Portable or rack 22 lbs Shipping weight 40 lbs

2. OPERATION

Power Connection

to operate on 105 - 125 V,
cps - 250 V, 50 cps - 420 cps power line,
to the power cord.

2.1.1 Line Voltage Conversion from 115 V to 230 V
For conversion from 115 V
connect the power trans-

terminal 4 and black-
terminal 5 and connect both to-
gether to terminal 5. Replace fuse F1 0.8 ampere by 0.5 ampere Slo-blo fuse. Detailed information for 115 V - 230 V conversion is given on the schematic at the end of this instruction book.

2.2 Starting Procedure

Insert the three prong plug into a proper ac power outlet. Use conversion unit where only two prong outlets are available. Move the power switch to ON position. The pilot light should glow. The instrument is ready for use after a short warm-up period.

2.2.1 Warmup Period

The instrument is usable after approximately 20 seconds. After 15 minutes the indication will be within [illegible] of the final value.

When the instrument has not been in use for many months or has been stored in high humidity allow a warmup period of at least one hour.

) SOURCE OF HEAT SHOULD BE CLOSE TO THE CK OF THE INSTRUMENT. PERMIT AIR TO CIRCU-TE FREELY AROUND THE VOLTMETER TO AVOID CESSIVE TEMPERATURE RISE IN THE INSTRUMENT.

[illegible] meter is calibrated in the vertical position. For convenience in reading, a tilting device is provided between [illegible] case.

3 Function of Controls See Figure No. [illegible] for control [illegible]

wer Switch ON — Turns the instrument on

nction Switch

NULL DETECT	The instrument operates as indicator for voltages normally below the voltmeter scale.
RMS METER	Instrument operates as voltmeter
MEAN SQUARE	Instrument operates as an ac to dc converter. The dc output proportional to the square of ac input voltage is available from MEAN SQUARE connector.
AMPLIFIER	The instrument operates as wide band amplifier with the output terminals at the rear of the case.

nge Selector

FULL SCALE .3 to 300 mV .3 to 300 V	Selects the voltage range in RMS METER or NULL DETECT operating mode. Changes the amplifier gain in 10 db steps in AMPLIFIER mode or dc mean square output in 20 db steps in MEAN SQUARE mode of operation.

2.3.1 Connectors and Terminals

INPUT	Type UHF connector for signal input. May be converted to binding posts with Ballantine Model 617 adapter.
GND	Ground binding post connected to the Voltmeter chassis and ground prong of the line cord.
MEAN SQUARE	Type BNC connector for dc output in MEAN SQUARE mode of operation
AMP OUTPUT	Four binding posts for floating, symmetrical or single ended amplifier output in AMPLIFIER mode of operation.

2.3.2 Controls — adjustable by screwdriver through the holes in the rear of the voltmeter.

LIN ADJ	Adjust electrically the down scale sensitivity in RMS METER and MEAN SQUARE mode of operation.
NULL ADJ	Adjust the rest position of the pointer in NULL DETECT mode of operation.
SENS ADJ	Adjust the instrument sensitivity in RMS METER, NULL DETECT and MEAN SQUARE modes of operation.

At the front of the instrument —

Indicator Screw — Adjust the down scale indication in RMS METER mode of operation

2.4 Voltage Measurement

For true rms voltage measurement:

Set	To
Function Switch	RMS METER
Range Selector	300 V

Connect the unknown voltage to the input and rotate the range selector counterclockwise until indication appears on the meter scale. Take reading from the scale indicated by the range selector. If the indication is down scale, below the red db scale, select the next lower voltage range to bring the indication close to full scale for best readability. Because of the logarithmic meter scale and Ballantine special design, the *accuracy of the measurement is the same at any point on the scale*, with a logarithmic scale indicator the pointer rest position is normally off scale.

At approximately every 200 operating hours or when the measurement with utmost accuracy is desired, check the scale adjustment

2.4.1 Scale Adjustment checks the scale linearity of the logarithmic indicator. It is equivalent to the zero adjustment in linear meter. For scale adjustment,

Set	To
Function Switch	RMS METER
Range Selector	1 V

Apply a stable 100 cps to 10 kc signal to the input. Adjust the amplitude to give an indication exactly on 10 on upper voltage scale. Rotate range selector to 3 V range. If the indication is not at 1.0 of lower voltage scale adjust the meter screw at lower center of the meter face until indication is 1.0 ±0.2%. Repeat the procedure until full scale indication on 1 V range agrees exactly with down scale indication on 3 V range.

Do not use the meter screw to bring the pointer on marked scale when no signal is applied to the voltmeter

5 Possible Error Sources

ne causes of some obvious measuring difficulties are listed iow

2.5.1 Pointer Stays Extreme Left when no signal is applied to the input, voltmeter is turned off or not connected to the power line, the input voltage is lower than the range selected, function switch is on MEAN SQUARE or AMPLIFIER position.

2.5.2 Indication Is High and the pointer stays on scale even after the next higher voltage range is selected. This happens when the function switch is in NULL DETECT position.

2.5.3 Pointer Stays Extreme Right when selected voltage range is too low or high hum is picked up by input circuitry.

cause of the wide frequency range and high sensitivity of e Model 320A, other measuring errors may be introduced nen proper measuring techniques are not used. The most mmon error sources are listed below. A more comprensive analysis of errors is given in NBS Conference on andards and Electronic Measurement paper: Techniques d Errors in High Frequency Voltage Calibration by Dr. Uiga and W. F. White. A copy of the paper is available om Ballantine Laboratories without charge.

2.5.4 Input Impedance and Loading Error

The input impedance of the Model 320A depends on the setting of the Range Selector and the frequency of the signal measured. It may be represented with a parallel combination of input capacitance and resistance

The input capacitance is 27 pF for ranges .3 mV to 10 mV and 11 pF for ranges 30 mV to 300 V. The variation of input capacitance with signal frequency is small.

The input resistance is 10 MΩ at low frequency. It changes with frequency as indicated in figure 3.

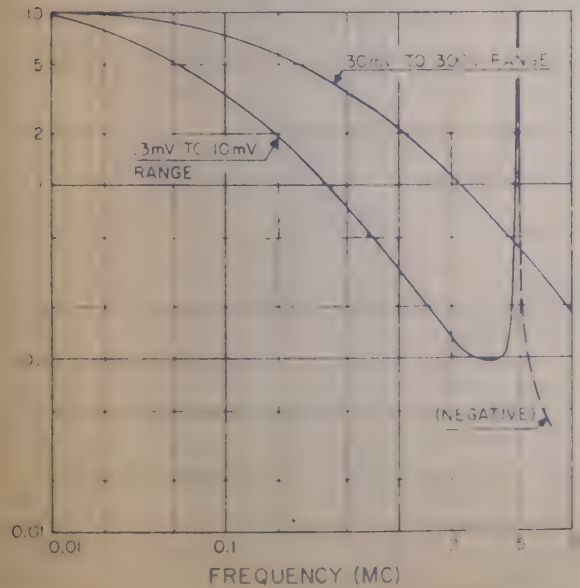


Fig. 3. Input Resistance Change with Frequency

As seen from the graph the input impedance on 0.3 mV to 10 mV ranges is negative at frequencies above 5 Mc

This may cause an undamped resonance circuit tuned to 5 - 10 Mc to oscillate when voltmeter is connected across it. When that occurs, connect a parallel resistor with value equal to the negative resistance of input impedance across the input of the voltmeter.

The effect of the voltmeter input impedance and the impedance of the connecting leads is to load, damp or detune the circuit. This should be considered when high impedance sources above 100 kΩ or tuned circuits are measured.

2.5.5 Ground Current Error is caused by the ground currents of signal or power line frequency which may flow through the ground connection. This current develops a voltage drop in ground connection. This is measured together with the signal. To reduce this effect the ground current should be kept minimum and the ground impedance kept as low as possible. The existence of the ground currents may be determined by measuring the ground lead current with an ammeter or clip-on current probe. To reduce the ground current connect all the equipment in the setup to the ground at one point, use insulation transformers or connect a several hundred ohm resistor in series with the ground prong of the power cord. This can easily be accomplished by using a 3 to 2 prong cord adapter and connecting the resistor in series with the ground wire from the adapter.

The impedance of ground connection may be made smaller by using as short a ground lead as possible Model 320A has a coaxial input which provides a low ground impedance. Use this coaxial input for measurement above 1 Mc wherever possible. For low frequency measurement the input may be converted to binding posts using Model 617 adapter.

2.5.6 Transmission Line Error is caused by transmission line effect in unmatched input leads. When 50 Ω cable is used this effect should be considered when measuring above 3 Mc and when line length exceeds 3 ft

2.5.7 Magnetic and Electrostatic Fields may cause pickup in the input leads or induce disturbances into the sensitive parts of the voltmeter. To reduce this effect use coaxial, shielded twisted or closely spaced input leads. Do not place the voltmeter close to strong sources of magnetic or electromagnetic fields. The most sensitive part of the voltmeter is the lower right corner where the input circuitry is located.

2.6 Use of the DB Scale

The db scale on Model 320A is based on dbv (1 mW into 1000 Ω) reference. To determine the dbv level, add the db indication from the red db scale to the db figure indicated on Range Selector. The dbv level may be converted to other reference levels by using conversion figures shown in Table I.

TABLE I

DB LEVEL CONVERSION

Reference Level	Conversion from dbv (1 mW/1000 ohms)
775 V, 1 mW in 600 Ω (dbm)	add 2.2 db
.732 V, 6 mW in 500 Ω	subtract 4.8 db
897 V, 6 mW in 600 Ω	subtract 5.6 db

simplify the conversion and to compute db levels of er references a handy db slide rule is available from ilantine Laboratories on request, free of charge.

Effect of Harmonics

case of complex waveforms with several harmonics the del 320A measures the true rms voltage independent of phase relationship of the harmonics.

$$E_{rms} = \sqrt{E_1^2 + E_2^3 + E_3^2 + \ldots + E_k^2} \quad (1)$$

E_{rms} — rms amplitude of the complete waveform

E_1 — rms amplitude of fundamental frequency component

E_2, E_3 — rms amplitude of harmonic frequency components

even some of the harmonic frequencies are beyond the meter's frequency range or fall into less accurate range, ir effect may be calculated by using the equation (1).

voltmeter response, although not calibrated, extends ve the specified 4 Mc limit. Except on the 0.3 mV range, response is down approximately 1.5 db at 6 Mc and 3 db Mc.

e use of the equation (1) is illustrated with the following mple:

ample:

500 kc square wave with the rms amplitude of 1.000 V measured. To achieve an accuracy of 0.1% the harmonics to 51 harmonics with maximum frequency of 25.5 Mc, uld be measured. When the Model 320A is used for asurement, the bandwidth is limited to 7 Mc or to 13th monic. Under those conditions the result would be 89 V or an error of 1.1%.

illustrate the effect of reduced accuracy for different monics, an assumption is made that the Model 320A d for measurement has the maximum negative error owed by specification, as shown in Table II.

TABLE II

MAXIMUM CORRECTION FOR HARMONICS

Harmonic	Error
1.5 Mc (3rd harm.)	3%
2.5 Mc (5th harm.)	3%
3.5 Mc (7th harm.)	5%
4.5 Mc (9th harm.)	5%
5.5 Mc (11th harm.)	10%
6.5 Mc (13th harm.)	30%

This assumption is not realistic because the voltmeter normally has positive and negative errors which tend to compensate one another. Using the formula for this hypothetical case, the result would be 0.984 V or an error of 1.6% or only 0.5% less than when measured with flat response instrument.

As a conclusion, the measuring accuracy is determined mostly by the accuracy of fundamental frequency or harmonics which have the highest energy contents. The harmonics with lesser energy contents have a small effect proportional to their energy contents (square of the amplitude). The effect may be calculated using equation (1) by considering only the harmonics which fall into the passband of the voltmeter and or by assigning the harmonics amplitudes corrected by the known error of the voltmeter.

2.8 Effect of High Crest Factor

The Model 320A measures with specified accuracy any complex waveform with the maximum crest factor (ratio of peak and rms amplitude) — 15 for a down scale indication — decreasing proportionally to a maximum 5 for full scale indication.

The crest factor may exceed those limits without affecting measuring accuracy if the following conditions are fulfilled:

a) the peaks occur only occasionally

b) the maximum crest factor of the peaks does not exceed 8 (fs) to 25 (ds)

c) the peaks have sharp or rounded tops

Higher crest factor than 8 (fs) to 25 (ds) always causes high error because of amplifier overload.

2.8.1 Flat Top Waveforms (pulses) with crest factor of more than 4 (fs) to 10 (ds) cause negative errors.

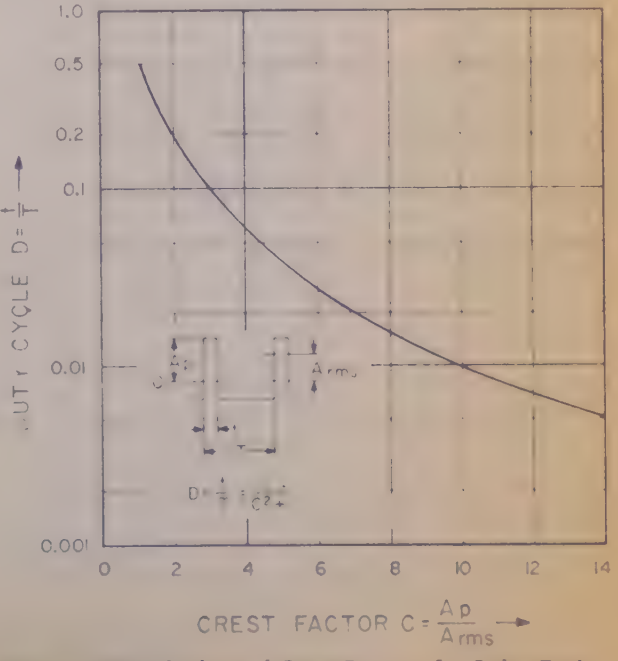


Fig. 4. Duty Cycle and Crest Factor of a Pulse Train

which may be as high as —2% for maximum crest factor 5 (ts) to 15 (ds). The error will increase rapidly with higher crest factor pulses, and the use of the voltmeter is not recommended.

The relationship of the crest factor to the duty cycles of a pulse train is shown in figure 4.

Effect of the DC Component

e Model 320A responds only to the ac component of a veform. If an unsymmetrical waveform which contains c component has to be measured, measure the dc comnent separately with a dc voltmeter and compute the e rms value by the equation (2):

$$E_{rms} = \sqrt{E_{dc}^2 + E_{ac}^2} \qquad (2)$$

ample:

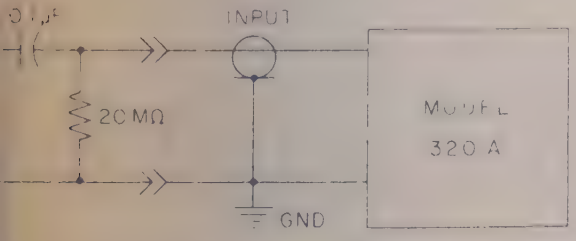
' dc is chopped into square pulses with 1 V peak ampli-. This pulse train has a dc component of 0.5 V which l be measured if the waveform is fed into a dc voltmeter. ac component of the waveform is a 0.5 V amplitude are wave with rms value 0.5 V which will be measured en the Model 320A is used.

total rms value of the waveform is

$$E_{rms} = \sqrt{E_{dc}^2 + E_{ac}^2} = \sqrt{0.5^2 + 0.5^2} = 0.707 \text{ V}$$

ch will be measured with thermocouple-type instruments ch respond both to ac and dc components.

dc component of the waveforms is blocked by the input acitor which has a 600 V dc rating. When more than V dc is superimposed on the ac voltage, use an external μF or higher blocking capacitor with proper dc rating connect a 20 MΩ resistor to the input as shown in re 5.



5. Connection of the External Blocking Capacitor

Measurement of Noise and Random Signals

noise and random signal measurement an error may be duced by the limited bandwidth and by the limit of mum crest factor. In case of white noise, the rms value e noise voltage E_{rms} depends on the bandwidth:

$$E_{rms} = K \sqrt{\Delta f} \qquad (3)$$

Δf — noise bandwidth (cps)

K — factor depending on the source

bandwidth of noise source is wider than the bandwidth Model 320A an error in noise measurement is intro-d. This error may be calculated from the equation (3).

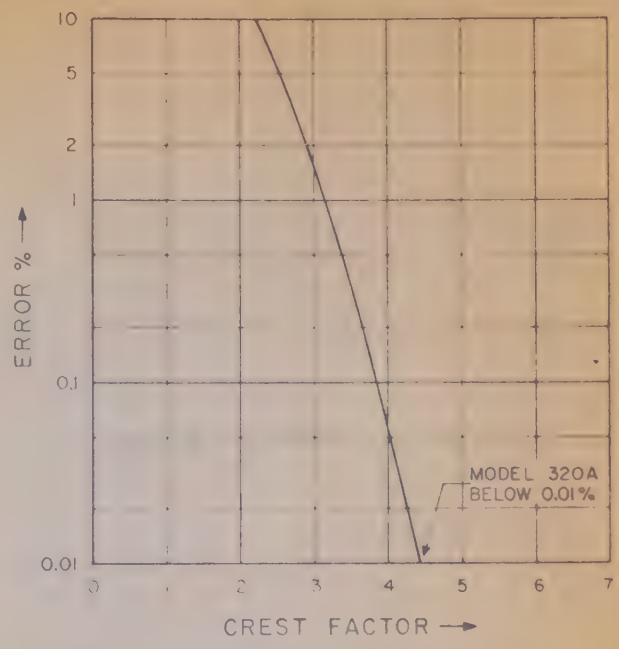


Fig. 6. Crest Factor Error with White Noise

For wide band noise measurement, 7 Mc may be considered as maximum bandwidth.

The crest factor limit also introduces an error. When measuring noise or random occurrences with Gaussian amplitude distribution, this error is depicted in figure 6. In the case of the Model 320A the crest factor limit of 5 introduces less than 0.01% error, which is negligible. However, when some circuit elements or preamplifiers introduce a more severe limitation of crest factor, the error should be considered when maximum crest factor limit approaches 3.5.

2.11 Measurement of Waveforms with Higher Crest Factor than 5

Waveforms up to crest factor 10 may be measured when the indication is limited to the lower half of the scale. To accomplish this, the input signal may be attenuated by a factor of 2 every time the indication comes to the upper half of the scale. An external attenuator, connected in front of the voltmeter, as shown on figure 7, may be used.

When the unknown voltage produces an indication on lower part of the scale, measure with switch in X1 position and

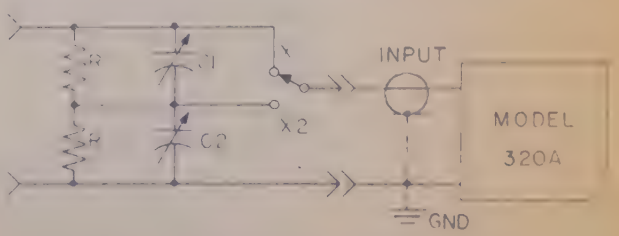


Fig. 7. Use of External Attenuator to Extend the Crest Factor Limit

irectly from scale. When indication falls in the upper f the scale, set switch to X2 position and multiply the tion by 2. Match the attenuator resistors to 0.1%. value depending on loading restriction, to the source. e of high values (above 1000 Ω) and when measuring frequencies, the attenuator should be compensated by tors C1 and C2. These should be adjusted to the ate 2 to 1 attenuation ratios at high frequency.

io transformer may be used for low frequency measure-s.

Measurement on .3 mV Range

effect of 24 μV internal noise level is negligible on all s except in 0.1 mV to 0.3 mV range. In this range it s approximately +3% error for 0.1 mV signal and error for 0.3 mV signal. Because of the noise and re-on of amplifier feedback, the accuracy of measurement e 0.3 mV range is reduced. The effect of noise can be cted, reducing the indication by the amounts shown ble III.

TABLE III

CORRECTIONS ON 0.3 mV RANGE
3% for 0.09 mV to 0.11 mV indication
2% for 0.11 mV to 0.14 mV indication
1% for 0.14 mV to 0.2 mV indication
0.5% for 0.2 mV to 0.31 mV indication

use of the reduced feedback, the falloff at the band ends re rapid than on the other ranges. The limits for crest r are the same as for all other ranges.

Measurement of Voltages Above 300 V

ages up to 10 kV may be measured with the Model 1320 in multiplier. This multiplier has a multiplication ratio 00 and has an input resistance of 40 MΩ in parallel 3 pF. The multiplier is usable from 5 cps to 1 Mc and s an additional measurement uncertainty of ±2%.

Use as Null Detector

he null detector mode, the voltmeter may be used for oximate measurements and nulling of voltages normally w the scale.

2.14.1 To Use the Model 320A as Null Detector

Set	To
Function Switch	NULL DETECT
Range Selector	Any Range

Now the pointer's rest position is moved from against the left hand stop to the lower part of the scale so that small changes in deflection can be observed. The lowest observable voltage change in 0.3 mV range is 1 to 2 μV. Therefore a null may be observed with very high precision.

2.14.2 For Approximate Voltage Measurements Below 100 μV

Set	To
Function Switch	NULL DETECT
Range Selector	0.3 mV

Short the input, adjust the NULL ADJ on the rear until pointer indicates 0 db on red scale. Apply voltage to the input and observe the indication. Use figure 8 to convert the indication to input voltage.

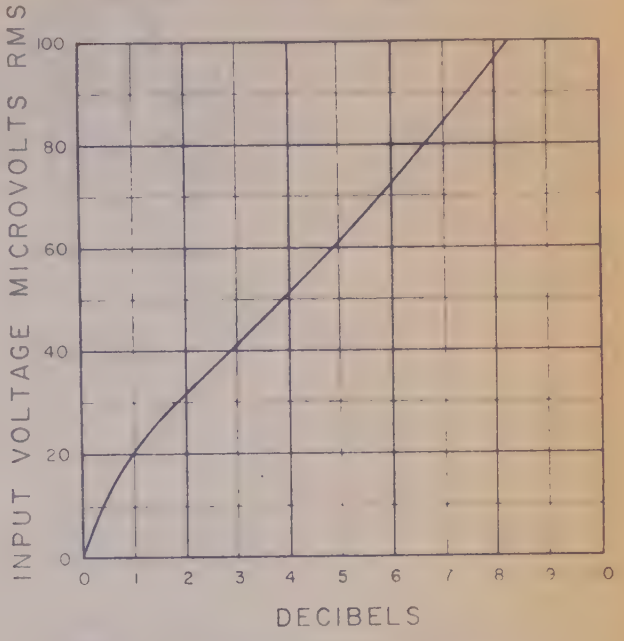


Fig. 8. Calibration of 0.3 mV Range on Null Detector Mode

The frequency response in Null Detector mode is the same as in RMS METER mode. The amplitude response deviates slightly from true rms. A small pointer jitter, caused by the noise of the voltmeter, is normal.

Return Function Switch to RMS METER position after finishing the measurement. This will avoid possible errors in subsequent use as voltmeter, when the position of Function Switch may be overlooked.

2.15 Overload Characteristics

The safe overload limits for extended periods are

Range	Max Voltage
0.3 to 10 mV	35 V
30 mV to 300 V	350 V

For a shorter period higher overloads up to 300 V on the most sensitive range will cause no damage.

2.16 Influence of Power Line Voltage

The Model 320A is operative over a 90 V to 130 V (180 V - 260 V) line voltage and 50 cps to 420 cps line frequency range. For ±10% variation of line voltage from 115 V (230 V) nominal voltage, the typical change in voltmeter sensitivity is given in Table IV.

TABLE IV

EFFECT OF LINE VOLTAGE

ltage Range	Frequency Range	
	20 cps - 1 Mc	5 cps - 4 Mc
mV to 300 V	±0.2% max	±0.5% max
0.3 mV	±0.3% max	±1.0% max

nall detector mode the pointer rest position is slightly cted by line voltage, readjust for accurate measurements.

7 RMS Current Measurements

Model 320A may be used together with resistances of wn value for making rms current measurements. The lantine Model 600 series of precision wirewound shunt stors is recommended for this purpose. These resistors available in the values of 0.01, 0.1, 1, 10, 100 and 1000 ns and are supplied in plug-in form for insertion across INPUT terminals. With these resistors, rms current of m 0.1 microamperes to 10 amperes can be measured. The t factor limit is the same as for rms voltage measurement. quency range is dependent on the shunt used.

8 Power Dissipation Measurement

use of the true rms response, the Model 320A may used in power dissipation measurements in a pure re- ve load. A voltage E (V) across a resistor R (Ω) ipates

$$P = \frac{E^2}{R} (W) \qquad (4)$$

ss a 600 Ω resistor the Model 320A measures dissipa- from 16.7×10^{-12} to 180 W. This corresponds to 10^{13} er ratio or 130 db. DB ratio could be read directly from db scale of the voltmeter. To convert that to standard rence level, such as dbm or other, use constants listed Table 1.

9 Use of Mean Square Output

del 320A may be used as a squaring ac to dc converter this mode.

Set	To
Function Switch	MEAN SQUARE
Range Selector	According to the Input Voltage

ms range, the input voltage which produces a full scale ection in voltmeter mode of operation produces a 2 V output. This changes proportional to the square ut voltage. The source resistance of output is 1000 Ω traded with 50 μF. The output follows the square law to aximum instantaneous input amplitude of 5 times the scale deflection. The maximum dc output is −1.0 V. n higher than 0.2 V output, the approximation of the re law has a negative error depending on the waveform.

oser approximation of square law over a wider range nput voltage is possible when the R76 1 kΩ resistor is changed to lower value. This change will proportionally decrease the output voltage.

The dc output reaches 90% of its final value in 0.1 second. The ripple on dc output is negligible at 1 kc and 50% at 5 cps. Longer or shorter response or averaging times can be achieved by changing the value of C56 50 μF capacitor. This will also decrease or increase the ripple. Use tantalytic capacitors with minimum voltage rating of 6 V.

In case a low resistance recorder or external indicator is connected to MEAN SQUARE output, the load resistor R76 may be disconnected. The current output from MEAN SQUARE connecter is −200 μA ±10% corresponding to full scale indication. Maximum available current is −2 mA.

The external device connected to MEAN SQUARE output should not apply any dc voltage to the output. This will affect the accuracy of square law.

2.20 Use as Amplifier

The voltmeter may be used as a stable, wide band amplifier.

Set	To
Function Switch	AMPLIFIER
Range Selector	According to the Input Voltage or Desired Gain
Output	Binding Posts at Rear

The maximum gain is 90 db ± 1 db bandwidth 5 cps to 4 Mc. Range Selector reduces the gain in 10 db steps until the lowest gain of −30 db on 300 V range.

The amplifier has a balanced transformer output which can be used floating, single-ended, or center tap grounded. For wide band operation ground the center tap.

The output from the output terminal marked IN PHASE is in phase with the input voltage. Voltage on REVERSE terminal has 180° phase shift with respect to input voltage.

The output voltage between IN PHASE and REVERSE terminals is 10 V when a signal which produces a full scale deflection in voltmeter mode is applied to the input.

The maximum distortion-free output signal is 50 V, for frequencies 30 cps to 500 kc. Outside this band the maximum available output voltage decreases to 10 V at 5 cps and 4 Mc. The voltage and gain between CT and IN PHASE or REVERSE terminals is 6 db less than the figures given above.

The source impedance at midfrequency is approximately 170 Ω from CT to IN PHASE or REVERSE terminal or 340 Ω from REVERSE to IN PHASE terminal. Between IN PHASE and REVERSE terminal the minimum allowable load resistance for 50 V maximum output is 20 kΩ, for 10 V maximum output 2 kΩ. The minimum loading resistor across half of the transformer output can be one-half of that value.

A maximum +300 V or −100 V dc can be applied between output transformer winding and chassis without causing damage.

3. CIRCUIT DESCRIPTION

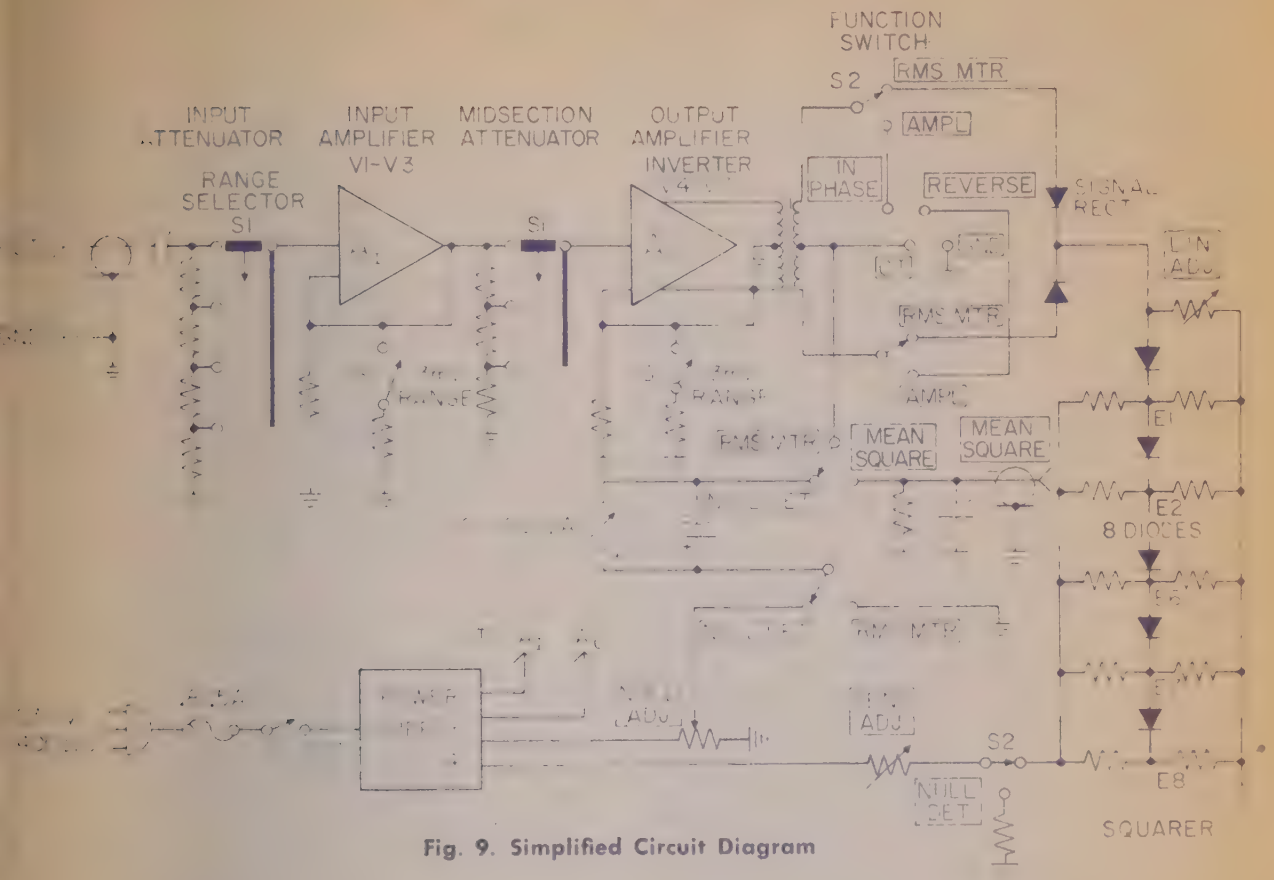


Fig. 9. Simplified Circuit Diagram

The basic voltmeter circuits are shown on simplified gram figure 9. A complete schematic is at the end of instruction book.

e basic parts of the voltmeter are:

Input and Midsection Attenuators

vo wide band attenuators are used in the Model 320A — input attenuator at the input and the midsection attenuor between the amplifiers.

The voltmeter sensitivity change on all ranges is achieved by input and midsection attenuator except on 0.3 mV range where the gain of the amplifiers is increased

3.1.1 Input Attenuator is connected to the voltmeter input over dc blocking capacitor. It consists of two separate attenuators R4, R6, and R4, R7, R8.

Below 20 kc the attenuator acts as a resistive divider; above 20 kc the attenuator is capacitive and attenuation ratio is adjustable with C6, C7 and C6, C8, respectively Stable, closely matched (0.1%) hermetically-sealed, deposited film resistors are used in attenuator. The attenuation ratios and the scale ranges on which the attenuator is in the circuit are shown in Table V.

TABLE V

ATTENUATION RATIOS

Voltage Range FULL SCALE	Input Attenuation Ratio	Midsection Attenuation Ratio	Total Attenuation Ratio	Total Gain of Amplifiers
.3 mV	1	1	1	84 db
1 mV	1	1	1	74 db
3 mV	1	3.162	3.162	74 db
10 mV	1	10	10	74 db
30 mV	31.62	1	31.62	74 db
100 mV	31.62	3.162	100	74 db
300 mV	31.62	10	316.2	74 db
1 V	1000	1	1000	74 db
3 V	1000	3.162	3162	74 db
10 V	1000	10	10000	74 db
30 V	31620	1	31620	74 db
100 V	31620	3.162	100000	74 db
300 V	31620	10	316200	74 db

3.1.2 Midsection Attenuator is a string type attenuator with resistors R40, R41 and R42. Because of the lower resistance values it acts as a resistive attenuator

over most of the voltmeter frequency range. Slight compensation at higher frequencies is achieved with C30 and C31.

The attenuation ratios with corresponding ranges are shown in Table V.

Input Amplifier is a stable, three-stage (tubes V1, and V3) feedback amplifier with a gain of 135 and with oximately 42 db of overall feedback. On 0.3 mV range ain of the amplifier is increased to 240 by shunting the ack resistor R20. R29 serves to vary the gain slightly its range.

high frequency response of the amplifier is adjustable ix with L1 on all ranges and with C20 on 0.3 mV only.

Output Amplifier is also a stable, three-stage (V4, ½ V7) feedback amplifier with a gain of 38 and with oximately 38 db of overall feedback. The last stage of mplifier is a direct coupled cathode follower for low t impedance. By shunting part of the feedback resistor mplifier gain is increased to 67 on 0.3 mV range. A high frequency adjustment on all ranges is possible C36 and C44.

ves one-half of the output transformer. The other half ven by the phase inverter.

Phase Inverter is a two-stage (V6, ½ V7) phase sing amplifier with the gain of 1 and with approxi- y 37 db of overall feedback. Together with output fier it drives the push-pull output transformer. The metry and balance of the drive is controlled by matched ors R65 and R66 at low frequencies and with C46 at frequencies.

Square Law Detector

rue rms response is achieved in the square law detector e the square law is synthesized by continuous sequence ear segments. With this technique a wide band, in- aneous responding, wide dynamic range, overload-proof ccurate rms response is accomplished. The ideal char- stic of a square law detector is

$$I_s = K \cdot E_s^2$$

I_s — squarer current

E_s — voltage applied to the squarer

K — constant

detector in the Model 320A approximates this law to 7% for smoothly varying waveforms and to ± 0.5% for sine waveforms.

The squarer consists of 8 series connected diodes CR4 - CR11. At every junction of diodes a pair of resistors (R82 - R91 for diode junction CR4 - CR5, etc.) supplies a dc bias and load to the junction. The bias voltage is increasing and the load resistance decreasing from diode CR4 to diode CR11. The signal, which is rectified in CR1, CR2 full wave rectifier passes through only the diodes whose bias is less than the instantaneous amplitude of the signal. At higher signal level more diodes are conducting, less load resistance is applied to the signal, and the squarer draws a current proportional to the square of the signal voltage. The rectified and squared current passes through a logarithmic indicator with 10 - 1 current range and 200 μA full scale sensitivity. Because of the square law of the detector, this current variation is produced by 3.16 - 1 input voltage range. The logarithmic scale of the indicator is retained with a voltage range of 10 db, even though the indicator has a current range of 20 db.

Capacitor C55, together with indicator movement inertia, averages the squared current. The diode CR3 is to protect the indicator from overload.

The sensitivity of the voltmeter is changed by changing the sensitivity of the square law detector by controlling the bias of all diode junctions with R71 SENS ADJ control. The temperature affects the forward characteristics of diodes, which are then compensated by the thermistor RT1.

In MEAN SQUARE output mode a 1000 ohm resistor R76, with averaging capacitor C56, is connected into the squarer circuit instead of the meter.

In NULL DET mode the squarer sensitivity is increased by disconnecting the bias on all diodes, and applying a small current in series with rectifiers and squaring network, which can be controlled by R77 NULL ADJ.

In AMP OUTPUT mode the squarer is disconnected and the transformer output connected to the output terminals for an ac output linearly proportional to the input voltage.

3.6 Power Supply

Two dc power supplies are used, one with silicon rectifiers CR12 and CR13 to supply dc filament power to the tubes V1 and V2. A regulated high voltage supply with V10 as rectifier supplies the high voltage to amplifiers and squarer. The B+ supply to the input amplifier is stabilized by the V11 and V12 cold cathode regulator tubes, to the output amplifier by V13 series regulator tube. A separate reference tube V14 stabilizes the bias voltage for squarer.

4. MAINTENANCE

General

Model 320A is designed for extended trouble-free operation. Use of high grade components operated below their rated values results in more than [illegible] expected operating periods without the need for [illegible] tube change.

The purpose of periodic maintenance is to [illegible] the specified accuracy, check the condition of the voltmeter and detect and replace deteriorated tubes or components before they have an appreciable effect on instrument performance. The procedure is designed not only to measure and correct voltmeter performance at the time of test, but to foresee the possible troubles and guarantee the instrument accuracy through the next maintenance period.

.2 **Recommended Maintenance** consists of three types f periodic checks

4.2.1 Meter screw adjustment after every 200 hours of operation.

4.2.2 1,000 hour check after every 1,000 hours of operation.

4.2.3 2,000 hour check after every 2,000 hours of operation.

.3 Necessary Maintenance Equipment

4.3.1 DC Voltmeter, range 0 - 500 V, accuracy ±3%, input resistance 10 MΩ minimum.

4.3.2 Stable AC Voltage Source, 0.4 to 2 kc, 0.1 to 10 V output.

4.3.3 Calibrated AC Voltage Source, 0.4 - 2 kc, 0.1 to 1 V output, accuracy ±0.25% or better. Ballantine Model 420 AC-DC Precision Calibrator or Ballantine Model 350 0.25% accurate RMS Voltmeter with any stable voltage source is recommended.

4.3.4 Tube Tester to measure tube transconductance.

4.3.5 Calibrated, Variable RF Voltage Source, 1 kc to 5 Mc. Ballantine Model 440 Micropotentiometer with 0.2 Ω resistor and 5 mA thermocouple and a RF generator is recommended

4.3.6 Variable Metered AC Power Supply 100 W

.4 Removal of the Case

lace the voltmeter front down on a table. Remove the ower cord and three #10 binder head screws at the rear f the case. Lift up the case. To replace the case proceed reverse order.

VARNING: When instrument is operated without the ase the danger of electric shock exists. Take extreme re not to come in contact with high voltage points.

he highest voltage on chassis is 450 V dc.

.5 Scale Adjustment

cale adjustment checks the scale linearity of the logarithmic ndicator. It is equivalent to the zero adjustment in linear eter. For scale adjustment:

Set	To
Function Switch	RMS METER
Range Selector	1 V

pply a stable 100 cps to 10 kc signal to the input. Adjust e amplitude to give an indication exactly on 10 on upper rmal scale. Rotate range selector to 3 V range. If the dication is not at 1.0 on lower voltage scale, adjust the ter screw at the center of the meter face until indication is . Repeat the procedure until full scale indication V range agrees exactly with down scale indication on V range.

[illegible] meter screw to bring the pointer on marked ce when no signal is applied to the voltmeter

4.6 1,000 Hour Check

The 1,000 hour check tests the performance of the voltmeter as a whole to detect unexpected failure of any tube or component and to insure trouble-free operation for the next 1,000 hours.

4.6.1 Tests Comprising the 1,000 Hour Check

4.6.1.1 Bias test of V7 tube

4.6.1.2 Meter screw adjustment

4.6.1.3 Line voltage stability test

4.6.1.4 Midband accuracy test

4.6.2 Bias Test of V7 Tube

This test determines the condition of V7 tube. For the test remove the case, connect the power cord to the voltmeter, allow 5 minutes warmup. Short the voltmeter input and

Set	To
Range Selector	300 V
Function Switch	RMS METER

Measure the potential between the cathodes (pins 3 and 8) and grids (pins 2 and 7) of each section of tube V7 - 6DJ8 (8223) located at the output amplifier printed board. Connect the ground lead of the DC voltmeter (4.3.1) to the cathode, high lead to the grid.

If either bias is below 1.5 V, replace tube. The tube replacement has negligible effect on voltmeter calibration. After test, replace the case.

4.6.3 Meter Screw Adjustment is made according to section 4.5.

4.6.4 Line Voltage Stability Test

This determines the condition of all tubes and detects any deterioration in tubes or components.

4.6.4.1 For the test, plug the voltmeter to a variable power supply (4.3.6). Set line voltage to 115 V ±1 V. Allow 20 minutes warmup. Connect a stable voltage source 0.4 - 2 kc (4.3.2) to the input of the voltmeter.

Set	To
Function Switch	RMS METER
Range Selector	300 mV or 10 V

Set the source voltage to produce indication exactly on some scale line.

4.6.4.2 Lower line voltage to 105 V ±1 V, wait 1 minute. Observe deviation from previous indication.

Limit of deviation 0.2% max

4.6.4.3 If the indication changes more than 0.2%, test the voltmeter according to 2,000 hour test described in section 4.7.

4.6.5 Midband Accuracy Test

Set line voltage to 115 V, allow minimum 30 minutes warmup.

onnect the calibrated voltage source to the voltmeter nput. Set the source voltage to 0.1 V ±0.25%.

Set	To
Function Switch	RMS METER
Range Selector	100 mV

Observe the indication on voltmeter. If the indication iffers from 100 mV more than 0.2% but less than 5%, adjust the SENS ADJ control at the rear until he voltmeter indicates 100 mV ±0.1%.

4.6.5.1 If the indication differs more than 0.5% from 100 mV, the error may be caused by misadjustment of SENS ADJ control or by changes in amplifier sensitivity. If the misadjustment of SENS ADJ is the cause, the sensitivity may be readjusted as described above. If the error is caused by changes in amplifier sensitivity, check the voltmeter according to section 4.7, the 2,000 hour check.

,000 Hour Check

2,000 hour check, besides testing the voltmeter as a , tests the tubes and some critical subassemblies. It sts the frequency response of the voltmeter.

.7.1 Tests Comprising the 2,000 Hour Check

4.7.1.1 Power supply test

4.7.1.2 Bias test on V7

4.7.1.3 Tube test

4.7.1.4 Meter screw adjustment

4.7.1.5 Line voltage stability test

4.7.1.6 Frequency response test

4.7.1.7 Midband accuracy test

.7.2 Power Supply Test

Remove the case, connect power cord to 115 V ±1 V upply. After 5 minute warmup:

Set	To
Function Switch	RMS METER
Range Selector	300 V

hort the voltmeter input.

Measure dc voltage on pin 8 of rectifier tube V10 - V4G

f the voltage is below 390 V replace V10.

Measure the bias of tube V13 - 12B4A between pins 1 nd 7 or between terminals F and H.

Replace tube V13 if bias is below 5 V.

4.7.2.1 Lower the line voltage to 105 V ±1 V, turn the voltmeter off and after 1 minute, on again. Observe V11 — OA2 and V12 — OB2 — both tubes should strike. Replace the tube which does not strike.

.7.3 Bias Test on V7 is made according to the sec- ion 4.6.2

4.7.4 Tube Test

Identify the tubes and sockets so that the tubes could be returned to the same sockets. Remove the tubes, check the tubes in a tube tester. Replace the tubes with transconductance less than the lowest limit specified by the tube manufacturer. Return the acceptable tubes to the original sockets.

4.7.4.1 Change of V7 - 6DJ8 (8223), V10 - 5V4G, V11 - OA2, V12 - OB2, V13 - 12B4A - has negligible effect on voltmeter performance and no readjustment or recalibration is needed after the tube change.

Replacement of V14 - 5651 may affect the sensitivity only.

Change of V5 - 6EJ7 may affect the noise and high frequency response above 2 Mc slightly Check of high frequency response is recommended when the utmost accuracy at higher frequencies is desired. Also hum check after replacement of V1 and V4 according to section 5.11.

Change of V5 - 6EJ7 may affect the voltmeter response above 1 Mc, and a frequency response check according to section 5.7 is needed.

4.7.5 Frequency Response Test

Connect the calibrated hf voltage source to the voltmeter. When Ballantine Model 440 Micropotentiometer is used, use setup shown in figure 10.

Set	To
Function Switch	RMS METER
Range Selector	1 mV

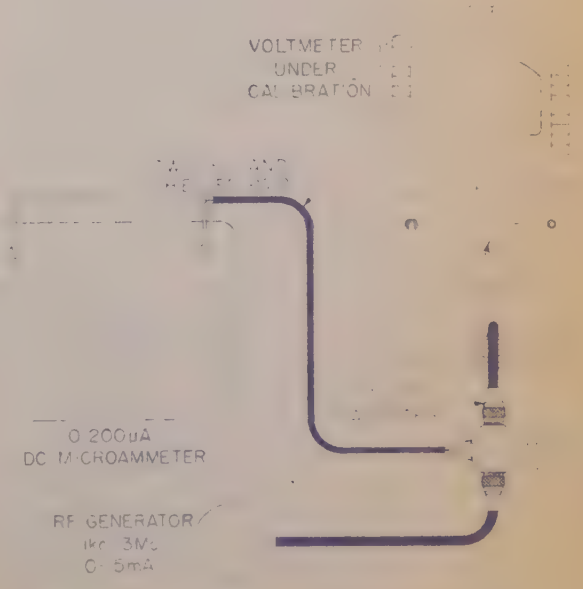


Fig. 10. Connection of Micropotentiometer

Set hf generator to 1 kc, adjust output to produce an indication exactly on a scale point at midscale (5, 6 or 7). Note the rf input level or indication on DC Microammeter when Model 440 is used.

4.7.5.1. Keep the input voltage to voltmeter constant (constant indication on Model 440 Microammeter). Change the frequency to 0.5, 1, 2, and 4 Mc. Observe the indication on Model 320A. It should differ from 1 kc indication not more than the following amounts:

+0, —1%	at	0.5 Mc
±1%	at	1 Mc
+2, —0%	at	2 Mc
±3%	at	4 Mc

Recalibrate the voltmeter according to section 5.7 if the deviation exceeds the limits stated above.

4.7.6 Midband Accuracy Test

Make the test as described under section 4.6.5.

5. SERVICE AND TROUBLESHOOTING

General

ase of voltmeter malfunction, limited servicing by the is feasible, provided skilled personnel and recommended pment are available and the procedures outlined below ollowed. However, it should be pointed out that deed procedures are only simplified outline of service and ration. Refined service and comprehensive calibration ires accurate and special equipment which normally is available to the user. Therefore if trouble develops n cannot be corrected by the simplified methods outd here, or when most accurate calibration of the voltr is needed, it is recommended that the voltmeter be rned to Ballantine Laboratories for service and recaliion. The instrument should in all cases be preceded by ter giving the exact nature and symptoms of the trouble. Section 6 for shipping instructions.)

Necessary Equipment

successful servicing and troubleshooting the following pment is needed:

5.2.1 DC Voltmeter, Ohmmeter, 0 - 500 V, ±3% accuracy, 10 MΩ or higher input resistance. RCA Voltohmist or equivalent.

5.2.2 Sensitive DC Voltmeter, 0.02 to 2 V, 1% accuracy, 1 MΩ or higher input resistance.

5.2.3 Sensitive AC Voltmeter, 1 mV to 100 V, frequency range 10 cps to 100 kc, ±3% accuracy 1 MΩ or higher input impedance. Ballantine Model 300H, 302C or similar voltmeter is recommended.

5.2.4 Signal Generator, 5 cps to 5 Mc, 0.1 mV to 30 V output.

5.2.5 Accurate RF Voltage Calibrator, output 1 mV, 10 mV, 30 mV, 1 V and 30 V, flatness of the frequency response ±0.25% from 1 kc to 4 Mc. Ballantine Model [illegible] Micropotentiometer with 5 mA thermocouple and [illegible] Ω, 2.2 Ω and 6.8 Ω resistors is recommended for [illegible] V, 10 mV and 30 mV standard.

Ballantine Model 393 HF Transfer Voltmeter with Model 1393-50 50 V probe is recommended for 30 V [illegible] 3 V probe for 1 V, [illegible]

5.2.6 Accurate Calibrated 1 kc Voltage Source, frequency 1 kc, voltage accuracy 0.25% output 1 mV to 6 V. Ballantine Model 420 AC-DC Precision Calibrator is recommended.

5.2.7 HF Diode Voltmeter, 0 - 50 V, input capacity 10 pF, or lower.

5.3 Simple Service Problems

5.3.1 Removal of the Case is required for service tests.

Place the voltmeter front down on a table. Remove the power cord and three #10 binder head screws at the rear of the case. Lift up the case. To replace the case proceed in reverse order.

WARNING: When instrument is operated without the case the danger of electric shock exists. Take extreme care not to come in contact with high voltage points.

The highest voltage on chassis is 450 V dc.

5.3.2 Pilot Light Replacement
Unscrew the red plastic cap. Remove the burned out pilot light from its bayonet base. Replace with Type 47, or Type 1815 bulb for longer life.

5.3.3 Fuse Replacement

For fuse replacement unscrew the fuse holder cap, pull out the fuse.

For replacement use

0.8 A Slo-blo ¼" x 1¼" fuse for 115 V operation

0.5 A Slo-blo ¼" x 1¼" fuse for 230 V operation

Investigate and correct the cause for fuse failure before replacing the fuse.

5.3.4 Tube Replacement is needed when the tubes in voltmeter show low transconductance, have developed grid current, heater cathode leakage or any other defect. All tubes which meet the tube manufacturer's specifications may be used — no special selection is needed. Some replacements require checks of the high frequency response as described under 4.7.4.1 or noise and hum check described under section 5.11. Do not replace tubes which check normal.

5.4 A DC Voltage Check is needed when voltmeter shows malfunction which cannot be corrected by tube replacement

5.4.1 For the check, remove the case, remove the shield on the input amplifier board, connect the voltmeter to 115 V ± 1 V power, short the input terminal and

Set	To
Function Switch	RMS METER
Range Selector	300 V

5.4.2 Measure the dc voltage at pin 8 of rectifier tube V10 - 5V4G.

Replace the tube if the voltage is below 390 V.

Measure the bias of the tube V13 - 12B4A between pins 1 and 7 or terminals F and H power supply printed board connector.

Replace the tube 12B4A if voltage difference between pin 1 and 7 is below 5 V.

5.4.3 Measure the pin voltages of all tubes with DC voltmeter. Compare the result with the values given on schematic. They should agree to 15%. If any voltage is outside the 15% limit, check the associated tube and components until the reason for deviation is found.

5.4.4 Check the grid current and biases of the tubes by measuring the grid voltages. The limits are shown in Table VI.

TABLE VI

GRID VOLTAGE LIMITS

Tube	Type	Pin	Voltage
V1	5654	1	0.01 V max
V2	6EJ7	2	0.3 V max
V3	6EJ7	2	0.3 V max
V4	5654	1	0.1 V max*
V5	6EJ7	2	4.2 V min
V6	6EJ7	2	4.2 V min
V7	6DJ8	7	1.5 V min**
	(8223)	2	1.5 V min**

* measured between pin 1 and terminal 21 of the output amplifier board

** measured between cathode and grid (pin 8 - 7 and 2 - 3)

Replace the tubes with excessive grid current.

5.4.5 See Section 4.7.4.1 for necessary adjustments after tube change. For dc voltages in square detector circuit see section 5.6.3.

Signal Tracing is recommended when the voltmeter indication cause cannot be found by dc voltage measure-

Signal tracing, remove the case, connect the voltmeter to 115 V power, apply 1 mV ± 1% 1 kc signal to the input,

Set	To
Function Switch	RMS METER
Range Selector	1 mV

Use the sensitive AC VTVM to measure the pin voltages. They should agree within ± 5% with the values marked in the schematic.

When measuring ac voltages check all voltages within the amplifier because in the feedback amplifier trouble in one stage may affect the ac voltages elsewhere in the circuit. Therefore location of an incorrect ac level does not necessarily pinpoint a trouble location.

If the signal voltage measures normal at the squarer input but incorrect indication is observed, check the square law detector and indicator circuit.

5.6 Check of Square Law Detector and Indicator is needed when the signal in amplifier circuit is normal but 5 V signal at the input of the rectified diodes CR1, CR2 (terminals 40 and 41) does not produce a full scale indication. The defect may be located by the following tests.

5.6.1 Continuity Test

For the test turn the voltmeter off.

Set	To
Function Switch	RMS METER
Range Selector	Any position

Measure dc resistance from input of CR1 or CR2 (terminal 40 or 41) to ground. The resistance should be approximately 600 Ω and a positive potential from terminal 40 or 41 to ground should cause the Model 320A indicator to deflect.

5.6.2 Diode Test

Measure the forward and reverse resistance of each diode in squarer circuit (CR1 to CR11) separately, using Voltohmist or similar instrument. The forward resistance is approximately a few hundred ohms. The reverse resistance 10 kΩ to 30 kΩ.

Replace the diodes which show shorts or are open. Use the types listed on parts lists. Use diodes which at room temperature have less than 0.5 μA reverse current when 0.5 V reverse voltage is applied.

5.6.3 Squarer Bias Test

For the test, turn the voltmeter on,

Set	To
Function Switch	AMPLIFIER
Range Selector	300 V

Measure dc voltages from diode junctions to chassis and compare with Table VII.

Replace the diode CR4 if the voltage at diodes CR1, CR2, CR4 is above 0.03 V. Use diodes listed in parts list. Check the reverse leakage which should be below 0.3 μA at 0.5 V reverse voltage and at 25° C.

If the junction voltage is outside the limits, check the diodes to higher voltage junction for leakage. Replace leaky diodes.

TABLE VII

SQUARER BIAS LIMITS

Diode Junction	Voltage at Diode Junction* Voltage on Terminal 43 65	70	75	Limit
R1, CR2, CR4	0.02	0.02	0.02	.03 max
R4, CR5	0.50	0.54	0.58	±3%
R5, CR6	0.84	0.90	0.97	±3%
R6, CR7	1.25	1.35	1.45	±3%
R7, CR8	1.87	2.0	2.15	±3%
R8, CR9	2.8	3.0	3.2	±5%
R9, CR10	4.2	4.5	4.8	±5%
R10, CR11	6.3	6.8	7.3	±5%
R11, R08	10.4	11.1	11.8	

*Interpolate the voltage values if the terminal voltage is not exactly 65, 70 or 75 V.

5.6.4 Electrical Linearity (R90) needs adjustment when the voltmeter has normal full scale sensitivity but the meter screw has inadequate range for bottom scale adjustment. The electrical linearity control R90 is located at the squarer board and may be adjusted through the hole marked LIN ADJ at the rear of the case.

5.6.4.1 For the adjustment turn the instrument on, allow 20 minutes warmup, then

Set	To
Function Switch	MEAN SQUARE
Range Selector	1 V

Apply a 1 V signal to the input. Connect a sensitive dc voltmeter to the MEAN SQUARE output connector on the front panel of the Model 320A. It should indicate approximately −0.2 V. Readjust the input signal until the output is −0.2 V ±0.5%.

5.6.4.2 Turn Range Selector to next higher (3 V) range. Adjust the R90 LIN ADJ until the output is −0.0206 V ± 0.5%. Repeat the steps 5.6.4.1 and 5.6.4.2 until the ouput is in specified limits at either range selector setting.

5.7 Frequency Response Alignment

Typical frequency response of the voltmeter with 1 kc response as reference is shown on figure 11.

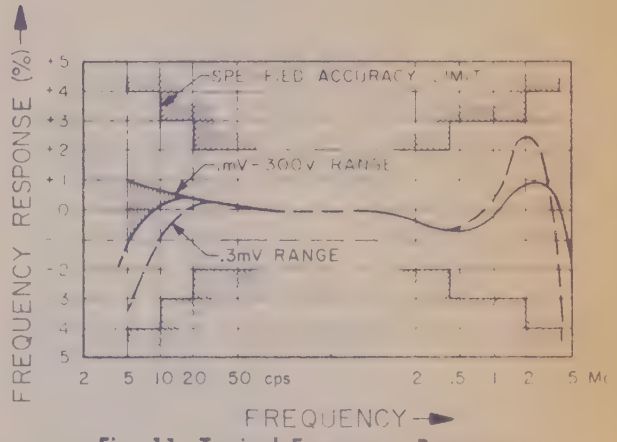


Fig. 11. Typical Frequency Response

If the frequency response at any range differs more than ±1 to 2% from the typical response shown in the graph, the response alignment is needed.

5.7.1 Low Frequency Response has no alignment controls. Its deviation from the normal response is

TABLE VIII

RESPONSE ALIGNMENT CONTROLS

Order of Alignment	Assembly	Adjustment	Affects Ranges	Adjust on Range
1	Amplifier	C44	all ranges	1 mV
2	Midsection Attenuator	C30	3, 100 mV; 3, 100 V	3 mV
3	Midsection Attenuator	C31	10, 300 mV; 10, 300 V	10 mV
4	Input Attenuator	C6	30 mV and up	1 V
5	Input Attenuator	C7	30, 100, 300 mV	30 mV
6	Input	C8	30, 100, 300 V	30 V
7	Attenuator Amplifier	C26	0.3 mV	0.3 mV

In case of an error on several ranges, this table helps to determine the control which has to be adjusted. A more detailed alignment procedure is outlined in Table IX at the rear of this instruction book.

caused by the changes of amplifier coupling or decoupling networks or deterioration of amplifier tubes. The most probable cause is the development of grid current in some stage. Normal response will be restored after the replacement of defective component or tube.

5.7.2 High Frequency Response may deviate from normal response because of the change in amplifier response or changes in attenuator compensation.

Amplifier response adjustment affects the responses of all ranges.

The attenuator adjustment offsets only certain ranges as indicated in Table VIII.

5.7.3 Amplifier Response Alignment is needed when the response of all ranges deviates from normal response.

Two controls are available for alignment. The Control C44 aligns the ranges from 1 mV to 300 V and a separate control C20 aligns the 0.3 mV range. C44 adjustment affects also 0.3 mV range and should be done before this range is adjusted.

5.7.3.1 For amplifier response adjustment remove the case, allow 5 minutes warmup and connect stable 1 kc to 5 Mc signal source 0.5 - 1 mV output to the input (Ballantine Model 440 with 5 mA thermocouple and 0.22 Ω resistor) as shown on figure 10.

Two steps are necessary for amplifier response alignment.

5.7.3.2. Phase Inverter Balance Check. This is needed when resistor R65, R66, R67 or tube V6 has deteriorated.

Set	To
Function Switch	AMPLIFIER
Range Selector	1 mV

Apply a 0.5 to 1 mV 1 kc signal to the input. Measure the voltage from CT to IN PHASE and REVERSE output terminal using diode voltmeter (5.2.7). The voltage at both output terminals should be equal within ±0.2%. If the voltage differs more, check R65, R66, and R67. R65 and R66 are matched pair to 0.1%.

5.7.3.3 Change the input frequency to 3 Mc. Measure the voltage at the same output terminals. If the voltage differs more than 0.2% adjust the voltage on IN PHASE terminals with C46 HF BAL control which is located at the tube side of output amplifier printed board until the voltage agrees with voltage at REVERSE terminal.

5.7.3.4 Amplifier Response Alignment. For the adjustment remove the case and

Set	To
Function Switch	RMS METER
Range Selector	1 mV

Apply a 1 kc 0.5 - 1 mV signal to the voltmeter through Model 440 Micropotentiometer (5 mA thermocouple with 0.22 Ω resistor). Adjust the signal to produce an indication directly to some scale line on the indicator. Note micropotentiometer dc output.

5.7.3.5 Change the signal frequency to 3 Mc. Adjust the RF amplitude exactly to the 1 kc amplitude applied to the voltmeter before by adjusting the level to the same dc output from micropotentiometer.

The indication on voltmeter should be ±0.5 to +1.5% above the previous indication. If not, adjust C44 on the output amplifier board until the indication is ±0.5 to +1% above the 1 kc indication.

5.7.4 0.3 mV Range Adjustment is needed when the response of 1 mV range is normal but 0.3 mV differs from the normal response. For the adjustment remove the case and

Set	To
Function Switch	RMS METER
Range Selector	.3 mV

Apply a 0.3 mV 1 kc signal to the voltmeter input through Model 440 Micropotentiometer (5 mA thermocouple with 0.22 Ω resistor). Adjust signal to produce indication exactly on some scale line; note the micropotentiometer dc output.

5.7.4.1 Change signal frequency to 3 Mc. Adjust rf amplitude exactly to 1 kc amplitude by adjusting the level to give the same dc output from the micropotentiometer. Adjust C20 through the left hole (see figure 13) on the shield at input amplifier board until the 3 Mc indication is within +2 to +3% of 1 kc indication.

5.7.5 C30 Midsection Attenuator Adjustment is needed when the voltmeter response on 1 mV range is normal but deviates from normal on 3, 100 mV and 3, 100 V range. For the adjustment, remove the case and

Set	To
Function Switch	RMS METER
Range Selector	3 mV

Apply a stable 2 - 3 mV 1 kc signal to the input. Use Model 440 Micropotentiometer (5mA thermocouple with 2.2 Ω resistor). Adjust signal to produce an indication at some scale line between 2 and 3. Note the input level.

5.7.5.1 Change signal frequency to 3 Mc. Adjust the amplitude exactly to 1 kc amplitude by adjusting level to give same dc output from the Micropotentiometer. Adjust C30 until voltmeter indicates +1 to 2% above the 1 kc indication. C30 is the top trimmer on Range Selector rear deck as shown in figure 14.

5.7.6 C31 Midsection Attenuator Adjustment is needed when voltmeter response is normal on 1 mV range but deviates from normal to 10, 300 mV and 10, 300 V ranges. For the adjustment, remove the case.

Set	To
Function Switch	RMS METER
Range Selector	10 mV

Apply a stable 1 kc 5 mV - 10 mV signal to the voltmeter through Model 440 Micropotentiometer (5 mA thermocouple with 2.2 Ω resistor). Adjust the signal for an indication on some scale line. Note the micropotentiometer dc output.

5.7.6.1 Change the signal frequency to 3 Mc. Adjust the amplitude exactly to 1 kc amplitude by adjusting level to give same dc output from the Micropotentiometer. Adjust C31 until voltmeter indicates 0 to 1% above 1 kc indication. The C31 is the lower trimmer on Range Selector near deck as shown in figure 14.

5.7.7 Input Attenuator Adjustments are made with the voltmeter in case. The trimmers are accessible through the front panel openings after removal of the escutcheon plate. For removal of escutcheon plate remove the function switch and range selector knob. Remove four #4 nickel plated binder head screws at the corners of the escutcheon plate and lift off the escutcheon plate. The adjustment holes under the escutcheon plate are marked on the panel.

Adjust the input attenuator in sequence shown on Table VIII or IX.

5.7.7.1 C6 Input Attenuator Adjustment is needed when voltmeter response on 1 mV range is normal but differs from normal on ranges from 30 mV and up.
For the adjustment:

Set	To
Function Switch	RMS METER
Range Selector	1 V

Apply a stable 1 V 1 kc signal to the voltmeter Monitor the signal with Model 393 Transfer Voltmeter (with 1393-2 probe) as shown in figure 11. Adjust the signal to produce indication exactly on some scale line. Register the level by balancing AC BALANCE on Model 393.

5.7.7.1.1 Change signal frequency to 50 kc. Adjust the level exactly to 1 kc level using Model 393 transfer voltmeter. Adjust C6 using insulated screwdriver until voltmeter indication agrees with 1 kc indication to ±0.2%.

5.7.7.2 C7 Input Attenuator Adjustment is needed when voltmeter response on 1 mV range is normal but differs from normal on 30 mV, 100 mV and 300 mV range.

For the adjustment:

Set	To
Function Switch	RMS METER
Range Selector	30 mV

Apply a stable 1 kc 20 - 30 mV signal to the voltmeter through Model 440 Micropotentiometer (5 mA thermocouple 6.8 Ω resistor). Adjust the signal to produce indication exactly on some scale mark. Note the dc output from Model 440.

5.7.7.2.1 Change signal frequency to 50 kc. Adjust signal amplitude exactly to 1 kc amplitude by adjusting the level to give same dc output from the Micropotentiometer. Adjust C7 until voltmeter indicator agrees with 1 kc indication to ±0.2%.

5.7.7.3 C8 Input Attenuator Adjustment is needed when voltmeter response on 1 mV range is normal but differs from normal on 30 V, 100 V and 300 V range.

For the adjustment:

Set	To
Function Switch	RMS METER
Range Selector	30 V

Apply a stable 30 V 1 kc signal to the input voltmeter. Monitor the signal with Model 393 Transfer Voltmeter (with 393-50 probe) as shown on figure 12. Adjust the signal to produce indication exactly on some scale line. Register the level by balancing AC BALANCE on Model 393.

5.7.7.3.1 Change signal frequency to 3 Mc. Adjust the level exactly to 1 kc level using Model 393 Transfer Voltmeter. Adjust C8 until voltmeter indication is +0.5 to 1.0% higher than 1 kc indication.

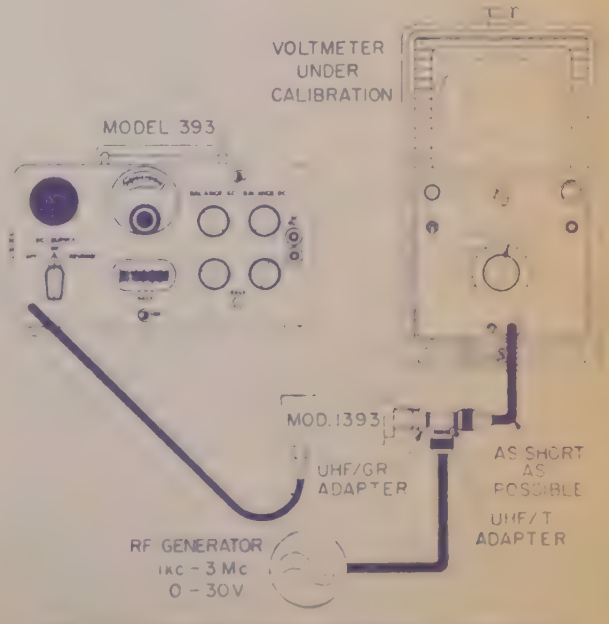


Fig. 12. Connection of HF Transfer Voltmeter

8 Sensitivity Adjustment

ie voltmeter has two sensitivity controls. R71 changes the nsitivity on all voltmeter ranges and R29 affects the sensi- ity of 0.3 V range only.

5.8.1 R71 Sensitivity Adjustment is needed when voltmeter exhibits similar error on all ranges at mid-frequency (1 kc). Approximate adjustment may be accomplished at any range, 1 mV or above, by adjusting the R71 sensitivity control at the rear of the voltmeter until voltmeter indication agrees with the 0.4-2 kc calibration signal. Make the adjustment after 0.5 hour minimum warmup. Change defective tubes or make adjustments of the frequency response before adjusting sensitivity.

5.8.2 R29 .3 mV Range Sensitivity Adjustment is needed when only .3 mV range is in error at mid-frequencies. If R71 adjustment is needed, it should be made before adjusting R29.

For the adjustment, remove the instrument from the case, allow 15 minutes warmup, and

Set	To
Function Switch	RMS METER
Range Selector	.3 mV

Apply a stable 1 kc signal 0.3 mV ±0.25% to the voltmeter and adjust R29 until voltmeter indicates 0.3 mV ±0.2%. R29 is located at the input amplifier board and is adjustable through the hole in the shield as shown in figure 13.

9 Table of Calibration Controls, their locations, ranges ey affect and frequencies and limits of adjustments are own at the end of the instruction book, Table IX.

10 Service of Attenuators

able, carefully matched resistors are used in the attenuator ney do not dissipate any appreciable power and therefore eir failure is very unlikely. Before replacing any resistors vestigate possible trouble sources such as grid current in be V1 or V4, bad switch contact, etc.

or the replacement, check voltmeter error at midfrequency n ranges 3, 10, 30 mV and 1, 10 and 30 V. Tabulate the ror. The error spread — maximum positive error less aximum negative error — should not exceed 0.3% because e attenuator resistors are matched to 0.1%.

one of the ranges shows more error than allowed within e 0.3% spread, one or more of the midsection or input renuator resistors must be defective. The defective string ay be determined from the schematic or from the Trouble- ooting Chart (section 5.15).

5.10.1 To replace an attenuator resistor measure the dc resistance of all resistors in the attenuator string with 0.05% or better accuracy. The resistance value may vary ±1% from the nominal value indicated on schematic but all resistors should be matched to [illegible]. Replace the resistor which differs more than 0.1% from correct matching. Use resistors of same type and make for replacement because different makes may have different high frequency characteristics.

5.10.2 After replacing the resistor, check error in all ranges and make sure that error spread does not exceed 0.3%. Adjust voltmeter sensitivity (R71 adjustment, section 5.8.1) so that maximum positive error equals approximately the maximum negative error. This condition gives the least measuring error.

5.10.3 Because of the close matching of the resistors a single replacement may not be obtained from Ballantine Laboratories and in most cases a whole string has to be replaced. For that reason it is recommended that the voltmeter be sent to Ballantine Laboratories for attenuator service.

5.11 Intrinsic Noise and Hum Test should be done after tube replacement (see section 4.7.4.1) or when instrument performs erratically on lower ranges, reads high on most sensitive range, or has high error when line frequency voltage is measured.

5.11.1 For noise check short the INPUT terminals of Model 320A.

Set	To
Function Switch	AMPLIFIER
Range Selector	.3 mV

Connect a wide-band voltmeter (4 Mc or more) to AMPLIFIER output terminals at the rear of Model 320A (high terminal to IN PHASE or REVERSE and low terminal to CT).

Measure noise voltage. Limit: 400 mV RMS maximum on .3 mV range and 125 mV RMS maximum on 1 mV range.

If noise is erratic or considerably higher, try new tubes starting in the order V1, V2, V4. VR tubes V11 and V12 may also be a source of erratic fluctuating noise.

The other possible noise sources are described in Troubleshooting Chart.

5.11.2 For hum check connect an oscilloscope to AMPLIFIER terminals of Model 320A.

Set	To
Function Switch	AMPLIFIER
Range Selector	.3 mV

Short INPUT terminals of Model 320A. Normal noise consists of wide-band noise with harmonics of power frequency relatively much lower or hardly noticeable. If high hum is present look for possible sources in Troubleshooting Chart.

5.12 Service of the Power Supply

The power supply dc voltages and typical ripple voltages are shown in the schematic at the end of the instruction book. In case of trouble, the dc and ripple voltage check will discover the most common faults.

e condition of VR tubes (V11, V12, V14) can be checked lowering the line voltage to 100 V and checking the rting of the tubes at low line voltage. Sometimes excess- e amplifier noise may be caused by the VR tubes which level may fluctuate slightly. Those tubes should be replaced.

The series regulator tube V13 for the output stage should have a bias of 5 V minimum between pin 1 and 2.7 with 115 V line voltage. Replace the tube with smaller bias.

5.13 Troubleshooting Chart

In the following chart the effects of possible malfunction of a component or maladjustments of controls are described:

Symptoms	Possible Cause	Pertinent Sections
Instrument inoperative Pilot light does not light up	No power; blown fuse; Defective power supply	5.3.3 5.12
Meter indicating with shorted input	Voltmeter in NULL DET mode; Defective tubes; defective coupling or decoupling capacitor or range selector switch, etc.	2.14 2.5.2
Meter indicating with no signal	Input not properly shielded; Voltmeter in NULL DET mode	2.5 2.14
Sensitive to mechanical shock	Microphonic tubes V1, V2, V4, etc.; Loose connection	5.11 5.5
High error at 60 cps measurement	Hum pickup through input wiring; High ground current; defective tubes V3, V4	2.5 5.11.2
High error at 120 cps measurement	Heater cathode short of V1, V2; High ripple of +B supply; open filter capacitors; inoperative VR tubes V11, V12; High dc heater ripple; Open bypass or decoupling capacitor	5.11 5.12
High error on lower part of the scale	Meter screw out of adjustment; Squarer control R90 out of adjustment	4.5 5.6.4
Instrument is out of calibration: a. on all ranges at low frequencies	Voltmeter in NULL DET mode; R71 SENS ADJ off; Defective tube or component; Meter screw off; defective diode in squaring network	2.14 4.6.5 4.5 5.6.2, 5.6.3
b. on all ranges at frequencies above 1 Mc	Amplifier frequency response off; Deteriorated tube; defective component	5.7.3
c. on every third range at low frequencies	Defective resistor in midsection attenuator	5.10
d. on every third range at frequencies above 1 Mc	C30 or C31 misadjusted	5.7.5, 5.7.6
e. on three sequential ranges at low frequencies	Defective resistor in input attenuator	5.10

Troubleshooting Chart (Continued)		
[illegible] on three sequential ranges at high frequencies above [illegible] kc	C56, C57 or C58 misadjusted	5.7.7
Sequential ranges don't agree	Meter screw or R90 LIN ADJ misadjusted; Diode CR3 leaky	4.5 5.6.3 5.6.3
Excessive flutter of pointer below 10 cps	Open C55	3.5
Pointer sluggish and positive errors at the bottom scale	Defective C55	3.5
High scale linearity error	Defective squarer diode or resistor	5.6

6. SHIPPING INSTRUCTIONS

If it should be necessary to return the instrument to Ballantine Laboratories, Inc. make certain that at least four inches of padding material surrounds the instrument to prevent damage during shipment. Ship via Railway Express or motor truck, to

Ballantine Laboratories, Inc.
90 Fanny Road
Boonton, New Jersey

TABLE IX

CALIBRATION TABLE

Order of Adjustment	CONTROL					CALIBRATION SIGNAL			Adjustment Limits %	Remarks
	Designation	Location	Controls	Affects Ranges	Adjust On Range	Recommended Source	Frequency	Accuracy		
1	R65, 66, 67	Output Amplifier Board TB3	H F. Balance of Phase Inverter	All	1 mV	Model 420 Calibrator	1 kc	Not Important	± 0.2%	Adjust for Equal Output from In Phase and Reverse Terminals to Chassis
2	C46	Output Amplifier Board TB3	H F. Balance of Phase Inverter	All	1 mV	Model 440, 5 mA TC, 0.22 Ω Res	3 Mc	Not Important	± 0.2%	
3	C44	Output Amplifier Board TB3	Amplifier H F. Response	All	1 mV	Model 440, 5 mA TC, 0.22 Ω Res	3 Mc	± 0.2% Reference 1 kc	± 0.5 to 1.5%	
4	C20	Input Amplifier Board TB2	3 mV Range H F. Response	3 mV	3 mV	Model 440, 5 mA TC, 0.22 Ω Res	3 Mc	± 0.2% Reference 1 kc	± 1 to 2%	
5	C30	Range Selector Rear Deck	Midsection Attenuator H F. Response	3, 300 mV	3 mV	Model 440, 5 mA TC, 2.2 Ω Res	3 Mc	± 0.2% Reference 1 kc	± 0.5 to 1%	
6	C31	Range Selector Rear Deck	Midsection Attenuator H F. Response	10, 300 mV 100 V	10 mV	Model 440, 5 mA TC, 2.2 Ω Res	3 Mc	± 0.2% Reference 1 kc	± 0.5 to 1%	
7	C6	Behind Escutcheon Plate	Input Attenuator H F. Response	30 mV 300 V	1 V	Model 395 with 1393-2 Probe	50 kc	± 0.2% Reference 1 kc	± 0.1%	
8	C7	Behind Escutcheon Plate	Input Attenuator H F. Response	30, 100, 300 mV	30 mV	Model 440, 5 mA TC, 6.8 Ω Res	50 kc	± 0.2% Reference 1 kc	± 0.1%	
9	C8	Behind Escutcheon Plate	Input Attenuator H F. Response	30, 100, 300 V	30 V	Model 395 with 1393-50 Probe	3 Mc	± 0.2% Reference 1 kc	0 to 1.5%	
10	R71	Rear, Through Hole	Voltmeter Sensitivity	All	1 mV - 300 V	Model 420 Calibrator	1 kc	± 0.2%	± 0.1%	
11	R29	Input Amplifier Board TB2	3 mV Range Sensitivity							

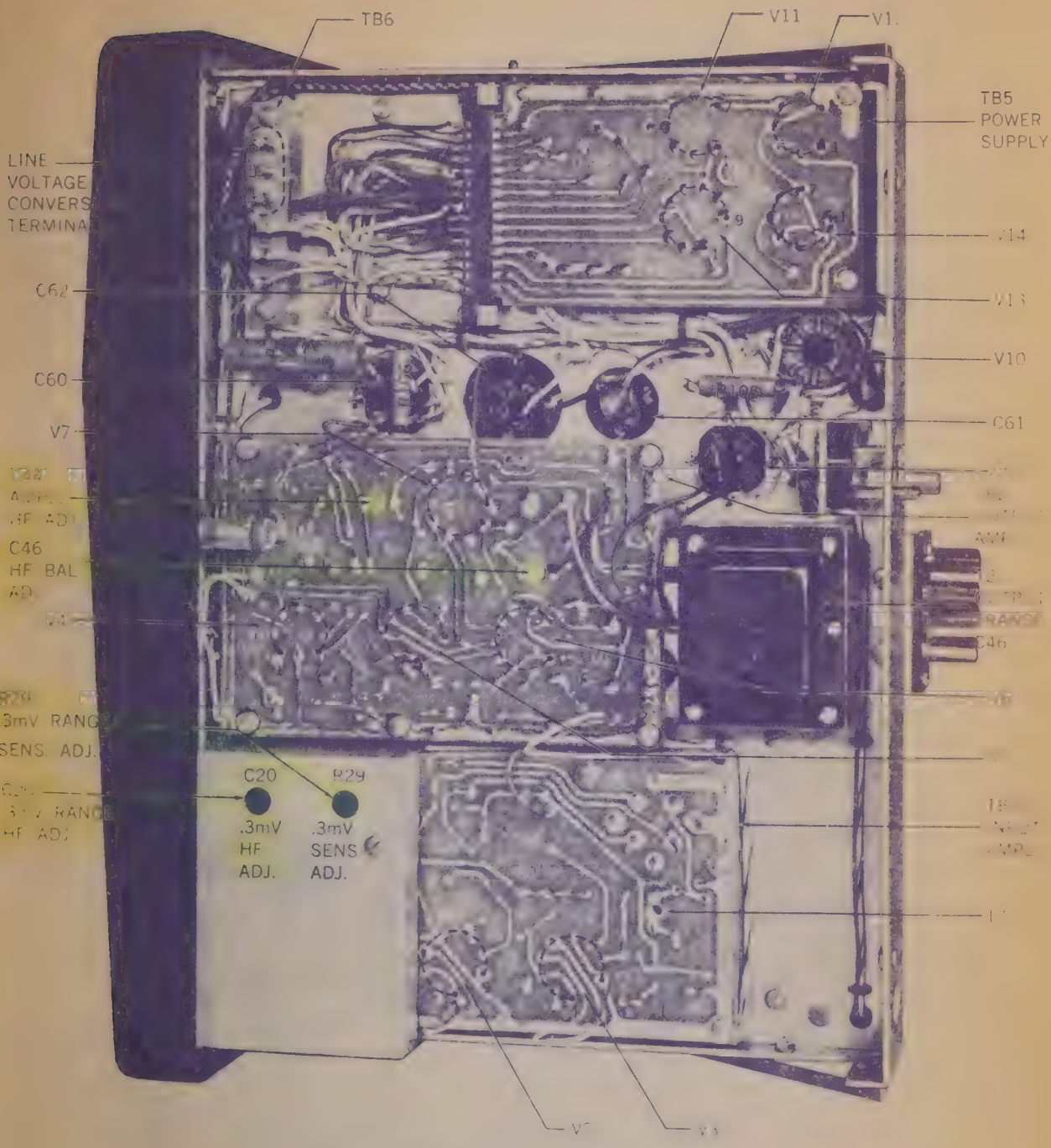


Fig. 13. Side View of Model 320A (right) Showing Location of Tubes and Adjustments

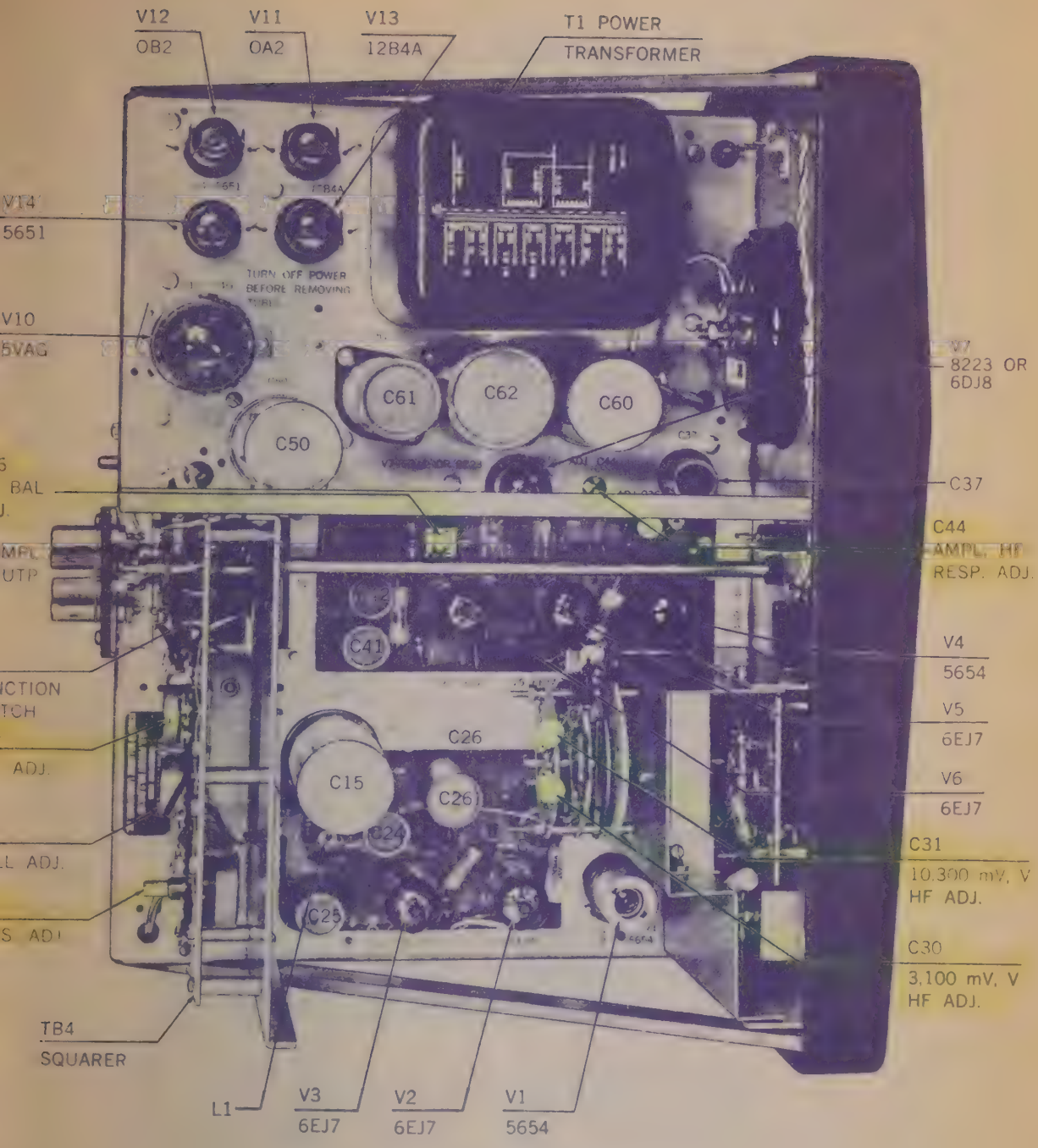


Fig. 14. Side View of Model 320A (left)
Showing Location of Tubes and Adjustments

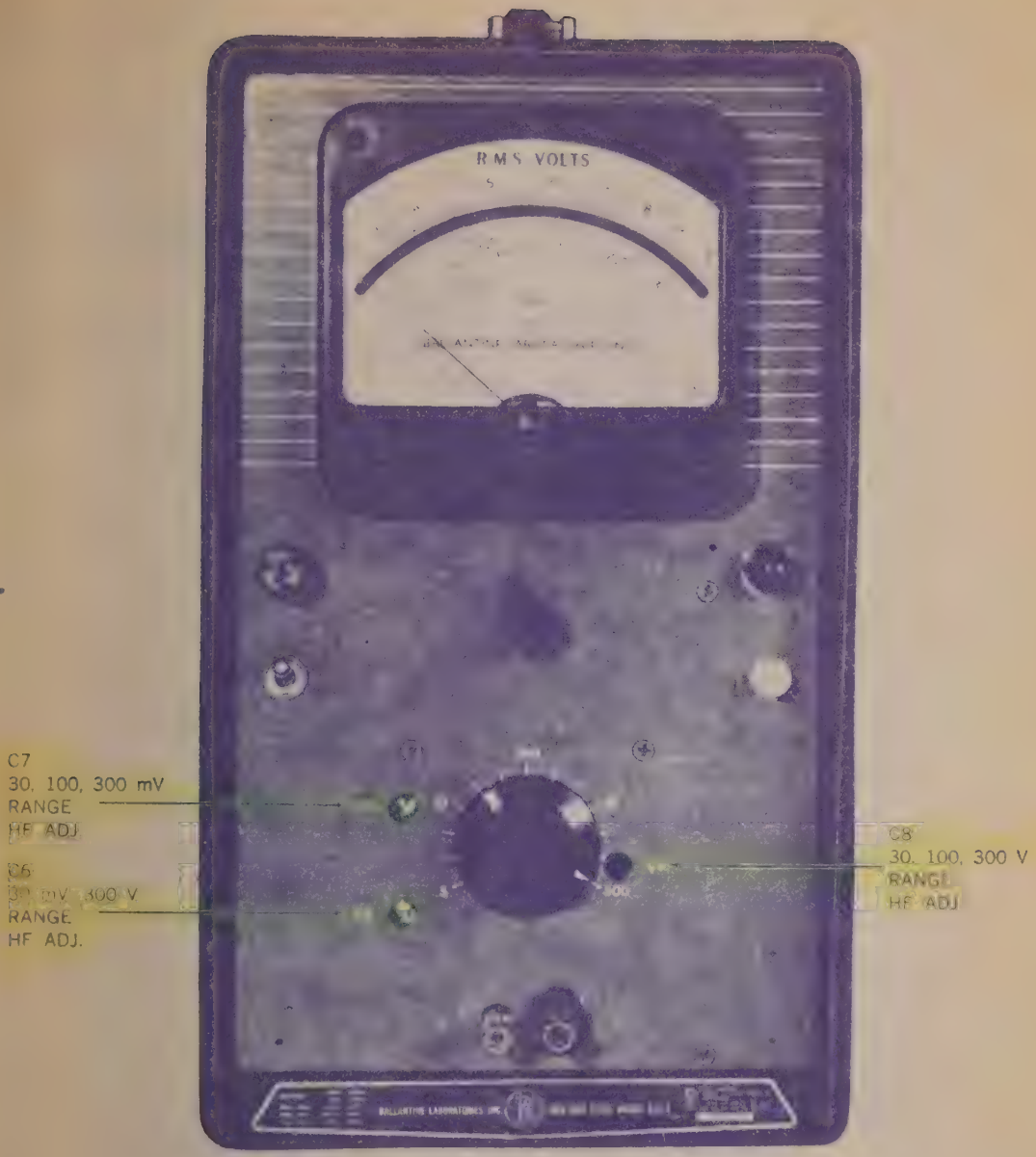


Fig. 15. Front View of Model 320A (escutcheon plate removed) Showing Location of Adjustments

8. REPLACEMENT PARTS LIST

ADDITIONS TO MODEL 820A CIRCUIT DIAGRAM, DWG MD-1627C

Ref. Symbol	Name	Description	Recommended
[illegible]	[illegible]	.056 uF, 10%, Type 148P56392, 600 V	Sprague
[illegible]	[illegible]	5500 pF, 5%, Type CM-30-E-552-J	El Menu
[illegible]	[illegible]	62 pF, 5%, Type CM-15-E-620-J	El Menu
[illegible]	[illegible]	39 pF, 10%, Type QC, 500 VDCW	Quality Components
[illegible]	[illegible]	15 pF, 5%, Type CM-15-C-150-J	El Menu
[illegible]	[illegible]	12 - 3.5 pF, Type 189-1-5, 850 V	[illegible]
[illegible]	C7	9 - 35 pF, Type N650, Style 538-002, 200 VDCW	Erie
[illegible]	[illegible]	9 - 35 pF, Type N650, Style 538-002, 200 VDCW	Erie
[illegible]	C11A	40 uF, -10%, +100%, Type PWP, 250 VDCW	Mallory
[illegible]	C11B	40 uF, -10%, +100%, Type PWP, 250 VDCW	Mallory
[illegible]	C11C	80 uF, -10%, +100%, Type PWP, 250 VDCW	Mallory
[illegible]	C11D	80 uF, -10%, +100%, Type PWP, 250 VDCW	Mallory
[illegible]	[illegible]	4 uF, +50%, -10%, Type 30D124A1, 6 V	Sprague
[illegible]	C17	.22 uF, 5%, Type 148P22492, 200 V	Sprague
[illegible]	[illegible]	150 pF, 5%, Type CM-15-E-151-J	El Menu
[illegible]	C21	12 uF, 250 V	[illegible]
[illegible]	C29	50-350 pF, Special	[illegible]
[illegible]	C31	.033 uF, 5%, Type 148P33392, 200 V	Sprague
[illegible]	C32	.001 pF, 20%, Type BYA-6S2, 600 VDCW	[illegible]
[illegible]	C33	250 uF, -10%, +100%, Type 8% D 117, 3 VDCW	Sprague
[illegible]	C36	12 uF, 250 V	[illegible]
[illegible]	C38	12 uF, 250 V	[illegible]
[illegible]	C39	50 uF, -10%, +100%, 250 VDCW	[illegible]
[illegible]	C40	2 - 8 pF, Type NPO, Style 538-002, 200 VDCW	Erie
[illegible]	C41	2 - 8 pF, Type NPO, Style 538-002, 200 VDCW	Erie
[illegible]	C43	.047 uF, 10%, Type 148P47392, 200 V	Sprague
[illegible]	C49	9 - 35 pF, Type N650, Style 538-002, 200 VDCW	Erie
[illegible]	C47	12 uF, 250 V	[illegible]
[illegible]	C48	.15 uF, 10%, Type 148P15492, 200 V	Sprague
[illegible]	C49A	100 uF, -10%, +100%, Type 30D114, 12 VDCW	Sprague
[illegible]	C49B	100 uF, -10%, +100%, Type 30D114, 12 VDCW	Sprague
[illegible]	C49C	.15 uF, 10%, Type 148P15492, 200 V	Sprague
[illegible]	C41	12 uF, 250 V	[illegible]
[illegible]	C42	12 uF, 250 V	[illegible]
[illegible]	C43	.005 uF, 20%, Type EGP Z5U, Style 851, 500 VDCW	Erie
[illegible]	C44	12 - 3.5 pF, Type 189-1-5, 850 V	[illegible]
[illegible]	[illegible]	62 pF, 10%, Type QC, 500 VDCW	Quality Components
[illegible]	[illegible]	12 - 3.5 pF, Type 189-1-5, 850 V	[illegible]
[illegible]	C50A	180 uF, -10%, +100%, Type FP, 200 VDCW	Mallory
[illegible]	C50B	80 uF, -10%, +100%, Type FP, 200 VDCW	Mallory
[illegible]	C50C	30 uF, -10%, +100%, Type FP, 200 VDCW	Mallory
[illegible]	C50D	20 uF, -10%, +100%, Type FP, 200 VDCW	Mallory
[illegible]	C51	50 uF, -10%, +750%, Type 30D170A1, 15 VDCW	Sprague
[illegible]	C52	50 uF, -10%, +750%, Type 30D170A1, 15 VDCW	Sprague
[illegible]	C53	20 uF, 20%, Type BYA-6S2, 600 VDCW	[illegible]
[illegible]	C54A	40 uF, -10%, +50%, Type FP-4448, 450 VDCW	Mallory
[illegible]	C54B	40 uF, -10%, +50%, Type FP-4448, 450 VDCW	Mallory
[illegible]	C54C	20 uF, -10%, +50%, Type FP-4448, 450 VDCW	Mallory

REPLACEMENTS PARTS LIST (Continued)

REFER TO MODEL 320A CIRCUIT DIAGRAM, DWG. MD-[illegible]27C

B.I. Part No.	Circuit Symbol	Capacitors	Manufacturer
	C60D	20 μF, −10%, +50%, Type FP-4448, 450 VDCW	Mallory
2756	C61A	1000 μF, −10%, +150%, Type WP, 15 VDCW	Mallory
	C61B	1000 μF, −10%, +150%, Type WP, 15 VDCW	Mallory
2020	C62	3000 μF, −10%, +150%, Type FP, 10 VDCW	Mallory
2586	C70	.02 μF, 20%, Type BYA-6S2, 600 VDCW	Cornell-Dubilier
2586	C71	.02 μF, 20%, Type BYA-6S2, 600 VDCW	Cornell-Dubilier
2372	C72	.02 μF, 20%, Type 355C223K, 200 V	Gudeman
2372	C73	.02 μF, 20%, Type 355C223K, 200 V	Gudeman
		Resistors	
1276	R1	5.6 ohms, 5%, Type GB	Allen-Bradley
1108	R2	180 ohms, 5%, Type EB	Allen-Bradley
1072	R3	39 ohms, 5%, Type EB	Allen-Bradley
2728	R4 [1]	10,000,000 ohms, 1%, Type PT-70	Pyrofilm
1015	R5	470,000 ohms, 5%, Type EB	Allen-Bradley
2729	R6 [1]	337,600 ohms, 1%, Type PT-500	Pyrofilm
2730	R7 [1]	9,703 ohms, 1%, Type PT-500	Pyrofilm
2731	R8 [1]	316,500 ohms, 1%, Type PT-500	Pyrofilm
1463	R15	10,000,000 ohms, 1%, Type CP-1	Wilkor
1064	R16	510 ohms, 5%, Type EB	Allen-Bradley
1064	R17	510 ohms, 5%, Type EB	Allen-Bradley
1687	R18	50,000 ohms, 1%, Type N-20	Corning
1084	R19	2,000 ohms, 5%, Type EB	Allen-Bradley
2734	R20	15 ohms, 1%, Type CP-1/2	Wilkor
1040	R21	20,000 ohms, 5%, Type EB	Allen-Bradley
1020	R22	1,000 ohms, 5%, Type EB	Allen-Bradley
1246	R23	220,000 ohms, 10%, Type CB	Allen-Bradley
1034	R24	39,000 ohms, 5%, Type EB	Allen-Bradley
1369	R25	20 ohms, 1%, Type CP-1/2	Wilkor
1690	R26	20,000 ohms, 5%, Type C-42	Corning
1686	R27	3,900 ohms, 5%, Type C-20	Corning
1064	R28	220 ohms, 5%, Type EB	Allen-Bradley
1935	R29	250 ohms, 20%, Type UPM-45	Chicago Telephone
1036	R30	33,000 ohms, 5%, Type EB	Allen-Bradley
1012	R31	750,000 ohms, 5%, Type EB	Allen-Bradley
1240	R32	220 ohms, 10%, Type CB	Allen-Bradley
1034	R33	39,000 ohms, 5%, Type EB	Allen-Bradley
1690	R34	20,000 ohms, 5%, Type C-42	Corning
1330	R35	3,000 ohms, 1%, Type CP-1/2	Wilkor
1066	R36	160 ohms, 5%, Type EB	Allen-Bradley
1041	R37	18,000 ohms, 5%, Type EB	Allen-Bradley
1040	R38	20,000 ohms, 5%, Type EB	Allen-Bradley
1327	R40 [2]	5,000 ohms, ±1%, Type CP-1/2	Wilkor
2732	R41 [2]	1,580 ohms, ±1%, Type CP-1/2	Wilkor
2733	R42 [2]	731 ohms, ±1%, Type CP-1/2	Wilkor
1061	R45	510 ohms, 5%, Type EB	Allen-Bradley

Resistors R4, R6, R7, R8 are part of a matched set and must be purchased as Set No. 1571.
Resistors R40, R41, R42 are part of a matched set.

REPLACEMENTS PARTS LIST (Continued)

REFER TO MODEL 320A CIRCUIT DIAGRAM, DWG. MD-1827C

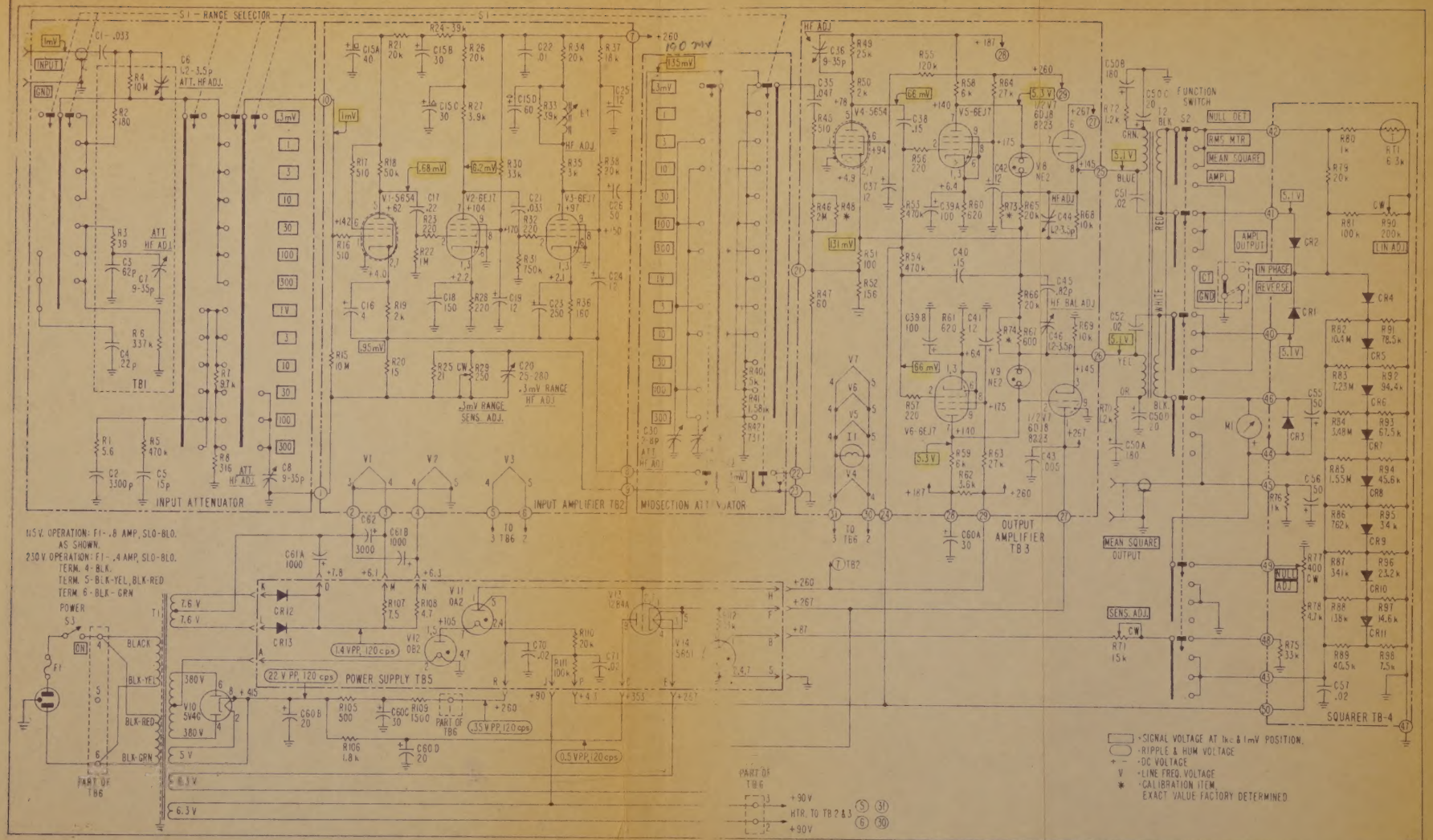
B. L. Part No.	*Circuit Symbol*	*Resistors*	*Manufacturer*
1007	R46	2,000,000 ohms, 5%, Type EB	Allen-Bradley
1358	R47	60 ohms, 1%, Type CP-½	Wilkor
1003	*R48	5,100,000 ohms, 5%, Type EB	Allen-Bradley
1001	*R48	10,000,000 ohms, 10%, Type EB	Allen-Bradley
1688	R49	25,000 ohms, 2%, Type C-32	Corning
1054	R50	2,000 ohms, 5%, Type EB	Allen-Bradley
1349	R51	100 ohms, 1%, Type RLS-1B	Dahlohm
1704	R52	156 ohms, 1%, Type RLS-1B	Dahlohm
1015	R53	470,000 ohms, 5%, Type EB	Allen-Bradley
1015	R54	470,000 ohms, 5%, Type EB	Allen-Bradley
1085	R55	120,000 ohms, 5%, Type EB	Allen-Bradley
1246	R56	220 ohms, 10%, Type CB	Allen-Bradley
1246	R57	220 ohms, 10%, Type CB	Allen-Bradley
1684	R58	6,000 ohms, 1%, Type N-20	Corning
1684	R59	6,000 ohms, 1%, Type N-20	Corning
1060	R60	620 ohms, 5%, Type EB	Allen-Bradley
1060	R61	620 ohms, 5%, Type EB	Allen-Bradley
1692	R62	3,600 ohms, 5%, Type C-42	Corning
1685	R63	27,000 ohms, 5%, Type C-20	Corning
1685	R64	27,000 ohms, 5%, Type C-20	Corning
1680	R65(1)	20,000 ohms, 1%, Type N-20	Corning
1680	R66(1)	20,000 ohms, 1%, Type N-20	Corning
1683	R67	600 ohms, 1%, Type N-20	Corning
1711	R68	10,000 ohms, 1%, Type RS-5	Dahlohm
1691	R69	10,000 ohms, 5%, Type C-42	Corning
1500	R70	1,200 ohms, 5%, Type EB	Allen-Bradley
1851	R71	15,000 ohms, 10%, Type 43-15 WW Pot	Clarostat
1100	R72	1,200 ohms, 5%, Type EB	Allen-Bradley
1036	R75	33,000 ohms, 5%, Type EB	Allen-Bradley
1682	R76	1,000 ohms, 1%, Type N-20	Corning
1984	R77	400 ohms, 20%, Type UPM-45	Chicago Telephone
1681	R78	4,700 ohms, 1%, Type N-20	Corning
1680	R79	20,000 ohms, 1%, Type N-20	Corning
1057	R80	1,000 ohms, 5%, Type EB	Allen-Bradley
1424	R81	100,000 ohms, 1%, Type DC-½	Electra
1404	R82	10,400,000 ohms, 1%, Type DC-½	Electra
1495	R83	7,230,000 ohms, 1%, Type DC-½	Electra
1373	R84	3,480,000 ohms, 1%, Type DC-½	Electra
1374	R85	1,550,000 ohms, 1%, Type DC-½	Electra
1417	R86	762,000 ohms, 1%, Type DC-½	Electra
1428	R87	341,000 ohms, 1%, Type DC-½	Electra
1427	R88	138,000 ohms, 1%, Type DC-½	Electra
1420	R89	40,500 ohms, 1%, Type DC-½	Electra
1918	R90	200,000 ohms, 20%, Type UPM-45	Chicago Telephone
1383	R91	78,500 ohms, 1%, Type DC-½	Electra

* Either one of these, or none, may be used, as determined during the calibration of the instrument.
(1) R65 and R66 matched to ± 1% of each other.

REPLACEMENTS PARTS LIST (Continued)

REFER TO MODEL 320A CIRCUIT DIAGRAM, DWG. MD-1827C

B. L. Part No.	*Circuit Symbol*	*Resistors*	*Manufacturer*
1382	R92	94,400 ohms, 1%, Type DC-½	Electra
1397	R93	67,500 ohms, 1%, Type DC-½	Electra
1398	R94	45,600 ohms, 1%, Type DC-½	Electra
1421	R95	34,000 ohms, 1%, Type DC-½	Electra
1429	R96	23,200 ohms, 1%, Type DC-½	Electra
1430	R97	14,600 ohms, 1%, Type DC-½	Electra
1423	R98	7,500 ohms, 1%, Type DC-½	Electra
1709	R105	500 ohms, 5%, Type 452-E-5015	Sprague
1707	R106	1,800 ohms, 5%, Type 452-E-1825	Sprague
1585	R107	10 ohms, 5%, Type BWH	IRC
1586	R108	4.7 ohms, 5%, Type BWH	IRC
1718	R109	1,500 ohms, 5%, Type 458-E-1525	Sprague
1040	R110	20,000 ohms, 5%, Type EB	Allen-Bradley
1679	R111	100,000 ohms, 1%, Type N-20	Corning
1689	R112	33,000 ohms, 5%, Type C-42	Corning
		Other Components	
1579	RT1	Thermistor, 6,300 ohms, ±10%, Type 36S1	Victory Eng.
5576	CR1, 2	Rectifier, Type 1N618	Amperex
5562	CR3	Diode, Silicon, Type SG22, or Diode, Type 1N816	
3144	CR4	Diode, Type S53G	Transitron
5555	CR5, 6	Diode, Type T 13G	Transitron
5555	CR7, 8	Diode, Type T 13G, or Diode, Type T 14G which does not fit in groups 2, 3 or 4	Transitron
5563	CR9, 10	Diode, Type T 14G, or Diode, Type T 13G	Transitron
5563	CR11	Diode, Type T 14G, or Diode, Type T 13G	Transitron
5579	CR12, 13	Rectifier, 500 mA, Type 1N1692, PIV, 50 V	Transitron
3419		Fuse, 0.8 amp, Type MDL Slo-Blo	Bussmann
3007	L1	Coil, Special	Ballantine
3190	M1	Meter, Taut Band	Ballantine
3061	T1	Transformer, Power	Ballantine
3060	T2	Transformer, Output	Ballantine
3126	V1, 4	Tube, Type 5654	General Electric
5593	V2, 3, 5, 6	Tube, Type 6EJ7	Amperex
5592	V7	Tube, Type 6DJ8	Amperex or Sylvania
3138	V8, 9	Lamp, Type NE-2	General Electric
3148	V10	Tube, Type 5V4G	RCA or General Electric
3106	V11	Tube, Type OA2	RCA
3322		Receptacle, Type 83-IRTY	Amphenol
3379		Receptacle, BNC, Type UG-1094/U INPUT CONN.	Amphenol



CAPACITORS: NOT MARKED—MICROFARADS (10^{-6} F)
P———PICOFARADS (10^{-12} F)
RESISTORS: NOT MARKED——OHMS (Ω)
K———KILOHMS (10^{3}Ω)
M———MEGOHMS (10^{6}Ω)
VOLTAGES: NOT MARKED——VOLTS (V)
mV———MILLIVOLTS (10^{-3} V)

Fig. 16. Schematic of Model 320A True RMS Voltmeter
Drawing No. MD-1827C

BALLANTINE LABORATORIES, INC.
Boonton, N. J.

MISSILE & SPACE SYSTEMS DIVISION
DOUGLAS AIRCRAFT COMPANY, INC.
SANTA MONICA, CALIFORNIA

MP MASTER
MA31998